Video Eyetracker Toolbox

User Manual

version 3.11 January 2006

Cambridge Research Systems Ltd

80 Riverside Estate
Sir Thomas Longley Road
Rochester
Kent ME2 4BH
England

www.crsltd.com

Version	Date	Changed by:	Description of Changes
3.11	18 Jan 06	M. Hodgetts S. Elliott	New sections for High-Speed Video Eyetracker Toolbox Revised videoEyetrace description Added MATLAB worked examples Appropriate commands from the CRS Toolbox for MATLAB described in the Appendix Description of COM Server interface removed

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Overview of Video Eyetracker Toolbox Family

This manual is intended to cover the hardware and software use of the Cambridge Research Systems Video Eyetracker Toolbox family of eye trackers. It is intended to be read only when all the steps in the corresponding Installation Manual have been successfully completed.

The Video Eyetracker Toolbox family of 50 Hz and 250 Hz video eye trackers share most of their functionality in common. As a result, this document will treat common functionality without reference to particular models and add sections specific to particular versions only where necessary.

The Video Eyetracker Toolbox allows you to add robust and accurate eye tracking to new or existing experimental systems. In addition, your Video Eyetracker Toolbox comes complete with a demonstration program called videoEyetrace which allows you to calibrate a test subject and present simple image files. If you have a suitable CRS Visual Stimulus Generator you can also use videoEyetrace to present smooth pursuit and saccade stimuli for oculomotor research. These topics are covered in detail in the following 2 chapters.

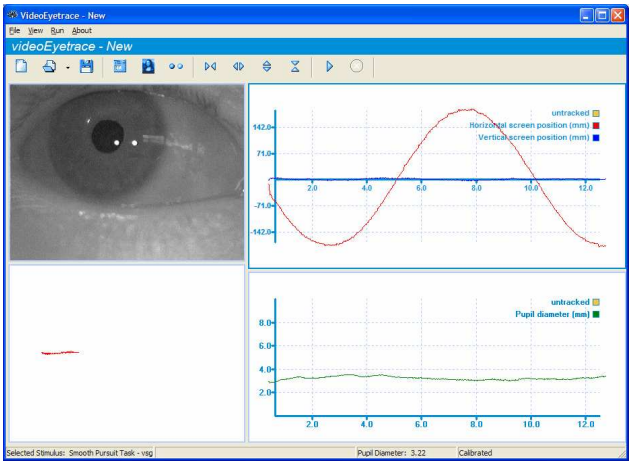

Fig 1. Smooth Pursuit Eye Movements

Once you become familiar with the operation of your Video Eyetracker Toolbox, you can exploit the Toolbox's open interface design either to:

- Integrate eye tracking functionality with your existing laboratory software or
- Write new eye tracking applications using a familiar programming environment.

Your Video Eyetracker Toolbox is designed to allow all aspects of its functionality to be accessed and controlled from MATLAB or any Windows programming tool that support Microsoft COM. A complete description of the MATLAB interface, including worked examples, is covered in the final chapter of this manual. A separate document describing the COM interface and examples in Delphi, C++ Builder and Visual Basic are available to download from the Cambridge Research Systems Support Portal (www.crsltd.com/support/login).

The 50 Hz version of the Video Eyetracker Toolbox is also compatible with Eye Response Technologies's GazeTracker ™ stimulus presentation and eye movement analysis software. GazeTracker™ is a powerful software package that consolidates stimulus presentation, information synchronisation, data analysis and visualisation. See our website (www.crsltd.com) for further information.

Fig 2. GazeTracker ™ Analysis of Dynamic Scene Content

CRS Video Eyetracker Toolbox

The Video Eyetracker Toolbox family of video eye trackers are designed to work with a standard PC running Windows XP without any custom processing hardware. Apart from the obvious difference in the range of supported video frame rates, from a user's perspective, all systems share most of their functionality in common. This document will therefore treat common functionality by default and only refer to specific systems where necessary.

50 Hz Video Eyetracker Toolbox

The 50 Hz Video Eyetracker Toolbox is a monocular eye tracker primarily intended for gaze tracking applications where the objective of the research is to determine where a test subject is looking and for how long. The videoEyetrace picture in Fig 1 is an example of where the 50 Hz system has been used to track a horizontal smooth pursuit target while monitoring pupil diameter.

The 50 Hz systems are supplied with one of two different camera configurations called: **Standard Camera** or **Standard Camera-I**. Standard Camera uses a progressive scan mode to acquire the video frames whereas Standard Camera-I uses an interlaced mode. Both will give equivalent performance but it will be necessary to select the appropriate type to match the supplied camera configuration before enabling the eye tracker. Standard Cameras are supplied unlabelled whereas Standard Camera-I versions are supplied with a label on the camera assembly.

High-Speed Video Eyetracker Toolbox

The High-Speed version of the Video Eyetracker Toolbox is a monocular video eye tracker primarily intended for oculomotor research. It provides a sampling frequency that is sufficient to capture the frequency spectrum of eye dynamics. Fig 3 shows where videoEyetrace has been used with a 250 Hz sampling rate to measure eye movements during a saccade task while monitoring pupil diameter.

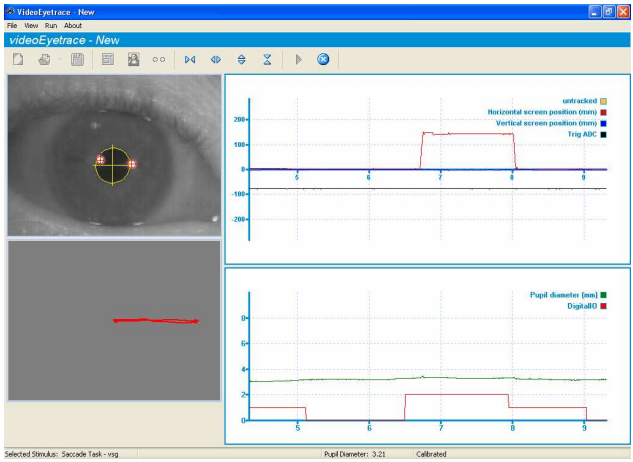

Fig 3. High-Speed Eyetracker with Saccade Stimulus

Images Acquired with 50 Hz and High-Speed Systems

The major difference between the 50 Hz and High-Speed versions of the Video Eyetracker Toolbox lies in the camera and illumination geometries required to operate at higher frame rates. The 50 Hz system uses a standard CCD sensor whereas the High-Speed version requires a CMOS sensor to operate at frequencies up to 250 Hz. In addition, the dual Purkinje glints generated by the infrared illumination sources will appear slightly larger in the images obtained by the High-Speed version as more illumination is required to obtain clear high contrast images.

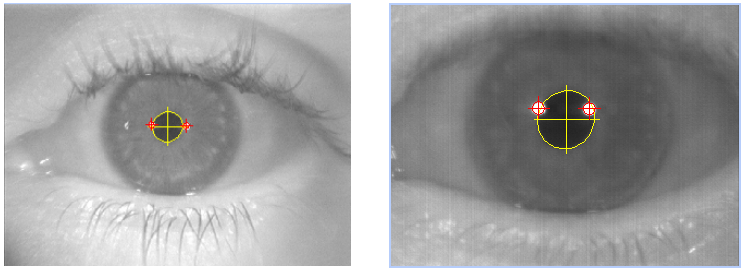

Fig 4. Comparison of 50 Hz (left) and 250 Hz (right) Images

Calibration

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Monitor Configuration and Calibration

The Video Eyetracker Toolbox is primarily designed to work in a dual computer screen configuration with separate displays for the Windows desktop and visual stimulus. It is also possible to use the system with a non computer-based display such as a TV, blackboard or LED array. However, in this scenario, you must manually configure and calibrate your display source and subject. To provide a second stimulus display, you can either use a single PC graphics card with dual outputs, two separate PC graphics cards, or a CRS Visual Stimulus Generator e.g. the ViSaGe.

Whichever solution you choose to use it is extremely important to correctly calibrate the stimulus display in terms of viewing distance, screen resolution and scale. The following sections describe the calibration process for each presentation device.

Dual VGA

If you are using the Toolbox in a Windows dual display configuration, you must calibrate the size of the stimulus display. The Toolbox assumes a minimum of two monitors; the Primary monitor is used to display Windows desktop and the Secondary monitor to display the visual stimulus. It is the size and resolution of this Secondary stimulus monitor that needs to be calibrated.

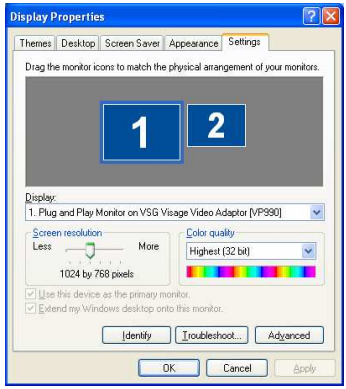

Fig 5. Display Properties

Before carrying out the calibration procedure ensure that the Windows desktop has been extended to both monitors and that the screen resolution and frame rates for the Primary (Windows desktop) and Secondary (stimulus monitor) agree with the minimum or recommended settings for both monitors as given in the Installation Manual. (If you intend to use videoEyetrace, your Primary and Secondary monitors must have a resolution of 1024 x 768 pixels.) These settings can be configured by a right mouse click on the desktop and choosing the **Properties** option to open the window shown in Fig 5.

Once the Primary and Secondary screens have been suitably configured, start the Toolbox's VGA Calibration application located in the Video Eyetracker Toolbox directory or from the desktop via **Start | Programs | Video Eyetracker Toolbox | VGA Calibration**. The VGA Calibration application will create a white square on a black background on the Secondary monitor and open the following window on the Primary monitor

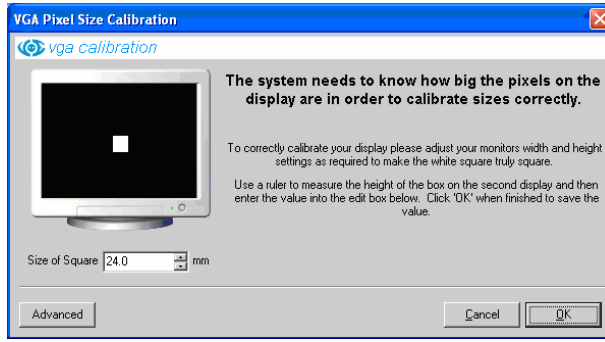
VGA Pixel Size Calibration
vga calibration
The system needs to know how big the pixels on the display are in order to calibrate sizes correctly.
To correctly calibrate your display please adjust your monitors width and height settings as required to make the white square truly square.
Use a ruler to measure the height of the box on the second display and then enter the value into the edit box below. Click 'OK' when finished to save the value.
Size of Square
24.0
mm
Advanced
Cancel
OK

Fig 6. VGA Pixel Size Calibration

To calibrate the Secondary monitor you must measure the width and height of the square using a ruler and, if necessary, adjust the horizontal or vertical scales on the display monitor itself to ensure that both measurements are equal. When the white stimulus is truly square, enter its height / width in the 'Size of Square' box and click **OK**. Note: this VGA Calibration procedure will need to be repeated if the screen resolution of the second monitor is subsequently changed in any way.

Now click the **Advanced** button to reveal the dialogue box shown in Fig 7:

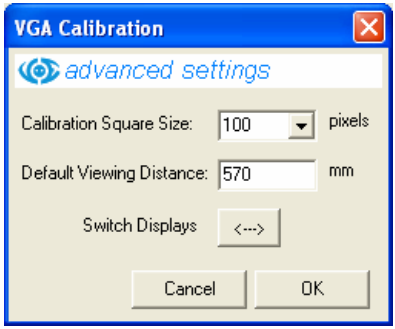

Fig 7. VGA Viewing Distance Calibration

To complete VGA Calibration it is necessary to measure and enter the correct Viewing Distance between the test subject and the stimulus monitor. This window also gives you the option of changing the size of the white calibration square to 200 or 400 pixels. This is sometimes preferable if working with high resolution monitors or if you are concerned with parallax measurement errors. If this is changed to a 200 or 400 pixel white square, it is important to measure and enter its new size as shown in Fig 6.

Dual VGA with GazeTracker™

GazeTracker operates in a different mode to the conventional Dual VGA setup in that the Video Eyetracker Toolbox User Interface controls (e.g. Calibration and Camera windows) and the GazeTracker program run on the Secondary monitor, while the VET calibration targets and stimuli presented by GazeTracker run on the Primary monitor.

To achieve this, click the **Switch Displays** button on the VGA Pixel Calibration Advanced Settings as shown in Fig 7 and then complete the VGA calibration procedure as described in the previous section for a standard Dual VGA configuration. Since GazeTracker uses the Primary Windows monitor to display stimuli, you may find it easier to use if you drag the desktop icons and Windows Task Bar onto the Secondary monitor's desktop.

CRS Visual Stimulus Generator

If you are using the Toolbox with a CRS Visual Stimulus Generator (e.g. ViSaGe or VSG2/5), you must configure the stimulus monitor using the VSG Software Library. First, open vsgDesktop from the Start menu via **Start | Programs | VSG Software Library | VSG Desktop** and click on the Monitor Configuration plug-in. A red and green chessboard will be presented on the VSG stimulus display.

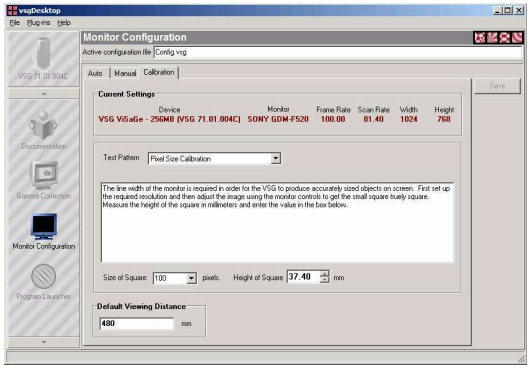
vsgDesktop
File Plug-ins Help
Monitor Configuration
Active configuration file Config.vsg
Auto Manual Calibration
Save
Current Settings
Device Monitor Frame Rate Scan Rate Width Height
VSG ViSaGe - 256MB (VSG 71.01.004C) SONY GDM-F520 100.00 81.40 1024 768
Test Pattern Pixel Size Calibration
The line width of the monitor is required in order for the VSG to produce accurately sized objects on screen. First set up the required resolution and then adjust the image using the monitor controls to get the small square truely square. Measure the height of the square in millimeters and enter the value in the box below.
Size of Square: 100 pixels. Height of Square 37.40 mm
Default Viewing Distance
480 mm
Documentation
Gamma Correction
Monitor Configuration
Program Launcher

Fig 8. Monitor Configuration within vsgDesktop

Now click on the **Calibration** tab (located in the main window of vsgDesktop). The chessboard will be replaced with a white square on the stimulus display. To calibrate this display you must measure the width and height of the square using a ruler and, if necessary, adjust the horizontal or vertical scales on the display to ensure that both measurements are equal. (Please note that the “The Size of Square” box gives you the option of changing from a 100 pixel to either a 200 or 400 pixel white square which will be easier to measure and will reducing parallax errors.) When the white stimulus is truly square, enter its height / width in the ‘Height of Square’ box.

To complete calibration it is also necessary to measure and enter the correct Viewing Distance between the test subject and the stimulus monitor in the Default Viewing Distance box. **Note**: although you can set the viewing distance parameter in your VSG program, the Toolbox’s calibration routines will use the value you

set here to create the calibration targets and determine your subject's direction of gaze.

Full details of how to configure the stimulus monitor are available by clicking on the vsgDesktop Documentation plug-in, as shown below. Note: that the VSG calibration procedure will need to be repeated if the screen resolution of the stimulus monitor is subsequently changed in any way.

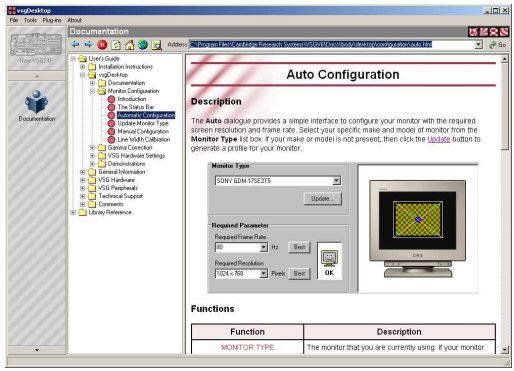
vsgDesktop
File Tools Plug-ins About
Documentation
Auto Configuration
Description
The Auto dialogue provides a simple interface to configure your monitor with the required screen resolution and frame rate. Select your specific make and model of monitor from the Monitor Type list box. If your make or model is not present, then click the Update button to generate a profile for your monitor.
Monitor Type
SONY GDM-175E2T5
Update...
Required Parameter
Required Frame Rate
Hz
Best
Required Resolution
1024 x 768
Pixels
Best
OK
Functions
Function
Description
MONITOR TYPE
The monitor that you are currently using. If your monitor

Fig 9. Documentation within vsgDesktop

Non-Computer-based Custom Display Device

If you are planning to use the Toolbox with a custom presentation device you cannot calibrate the device directly. Instead you must define the bounding dimensions of the device using the Toolbox's programming interface. This can be achieved using the function **vetSetDeviceParameters** and passing the parameter **CRS.deUser** followed by the **viewing distance** and finally the **Width** and **Height** of the device.

Setting the Toolbox's presentation device to **CRS.deUser** activates the **vetSetCallbackInitialiseDisplay**, **vetSetCallbackClearDispla***y* and **vetSetCallbackDrawTarget** event/call-back procedures during the subject calibration process. These call-backs can then be used to present targets at defined locations to the subject during calibration. More information regarding vetSetDeviceParameters and the callback functions can be found in the *Appendix A* at the end of this manual.

Positioning and Focusing your Subject (Imaging)

The EyeLock headrest is designed to image the eye in a way that is both safe and minimally invasive to the subject. It achieves this via an infrared mirror, which appears transparent to the subject while keeping the camera, and illumination sources out of their field of view.

The Toolbox is designed for robust operation over a wide range of subjects and will easily meet its quoted technical specification if used with care. It is therefore important that your subject's eye is imaged under the best possible conditions. This will be achieved by carrying out the following instructions:

1. Ensure that the surface of the stimulus display is both centred and perpendicular to this subject's view axis.

2. Position the subject's head so that their chin is resting on the chin-rest and their forehead is resting against the head-strap. The height of the chin-rest and head-strap should be adjusted so that the subject is comfortable and their eye is level with the centre of the presentation display, as shown below. **Note**: the subject's head should not be tilted as this may cause the eye lid to obscure the pupil.

Fig 10. Correct Viewing Geometry

WARNING: When adjusting the height of the chin-rest over large distances it is advisable to use one hand to rotate the adjuster knob and the other hand to guide the other end of the chin-rest in the desired direction (see Fig 11). This also applies to moving the camera assembly.

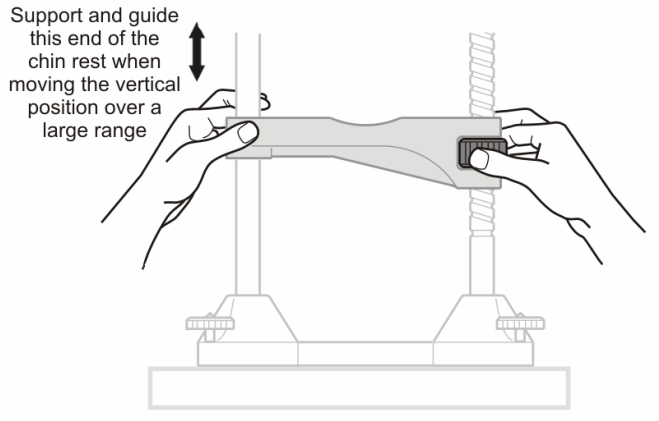

Fig 11. Adjusting the Chin-Rest

3. Use the MATLAB calibration scripts (see page 24) or another application that uses the Toolbox's functionality.

4. Remove the camera lens cover. Ensure that the camera lens and infrared mirror are free of dirt or fingerprints using the supplied lint-free cloth.

5. While the subject is still and viewing straight ahead, adjust the height of the camera assembly so that the subject's eye appears vertically centred within the Toolbox's camera window.

6. Horizontally position the subject's eye inside the camera window by adjusting the horizontal position of the camera. This is achieved by releasing the locking screw located at the back of the camera assembly and sliding the camera case in the corresponding direction. Make sure that the locking screw is gently tightened once the correct location is found.

WARNING (High-Speed System Only): The High-Speed camera can get very warm when used for extended periods. The camera case acts as a heat sink for the electronics inside and therefore runs at an elevated temperature. This is normal but your users should be aware of this.

7. While the subject is still looking straight ahead, rotate the focussing ring until the subject's pupil (not their eyelashes or eyebrow) appears as sharp as possible in the video image.

8. Ensure that both Purkinje reflections remain distinct from any bright secondary glints. This may occur if the subject is wearing glasses or if the ambient illumination contains a significant infrared component. The Toolbox is designed to cope with any number of secondary glints provided they are either not as bright as the Purkinje reflections or do not lie close to the pupil.

   You should now be able see an image of the subject's eye similar to Fig 12.

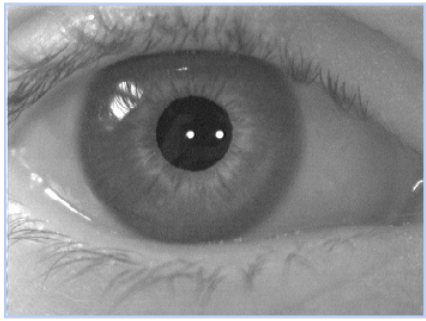

Fig 12. Typical Video Image of Eye

9. Lastly, before performing a calibration, ask the subject to view the four corners of the stimulus screen. Ensure that the two Purkinje glints remain compact and maintain constant separation over the full range of intended eye movements. If not, it will be necessary to reduce the range of intended eye rotations to ensure that both Purkinje glints always lie on the corneal surface. This can be achieved by moving the stimulus screen further away from the eye or by changing the 'Screen

Scale Factor' in the Advanced Calibration Settings (see next section). **Note:** if you move the stimulus display, you must re-measure the Viewing Distance and set the new value using the scheme appropriate to your graphics configuration (see the Monitor Configuration section in this chapter for details).

Subject Calibration

Calibration enables the Toolbox to learn the relationship between where a subject is looking and where their pupil and Purkinje glints appear in the video image. This is achieved by asking your subject to fixate on a number of screen targets whose positions are known to the system. Once calibration is complete, the Toolbox will be able to calculate all subsequent viewpoints directly from the image data. Subject calibration works as follows[1]:

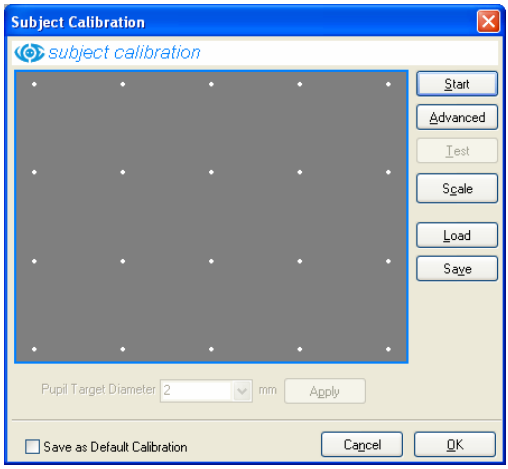

Fig 13. Calibration Window with Default Settings

The calibration window in Fig 13 can be displayed using one of the supplied demonstration scripts which are part of the CRS Toolbox for MATLAB. These can be downloaded from our

[1] Note: these instructions assume the subject has been positioned correctly with their eye in focus and that the stimulus monitor has been calibrated for pixel size and viewing distance. For more information consult the previous sections.

Support Portal (www.crsltd.com/support/login) (see Appendix A on page 81). The calibration scripts are saved by default in the vetDemos folder.

You need to run either **demoVETcalibrationVGA** or **demoVETcalibrationVSG** depending on whether you have a Dual VGA or CRS Visual Stimulus Generator monitor setup. This will create and display the Toolbox's Calibration window as shown in Fig 13. (Note: this window can also be accessed by clicking on the Calibrate icon (Fig 14) within videoEyetrace. If the Calibrate icon appears greyed out, you need to make sure you have initialised your VET camera by choosing the appropriate type using the **Select Video Source** on the **File** menu – see videoEyetrace chapter on page 35 for further details.)

Fig 14. Calibrate Icon

Pupil Scale Calibration

To obtain accurate data regarding the diameter of your subject's pupil you need to calibrate the Toolbox so it knows the geometric scale of the video image it is being fed[2]. Once the correct scale factor has been set the Toolbox will be able to determine pupil diameter to within a few hundredths of a millimetre.

Note: The scale factor does not have to be calibrated in order to track a subject's gaze position correctly.

To calibrate the scale factor for your subject follow the instructions below:

1. Temporally remove the subject's head from the EyeLock headrest.

[2] Changing the focus point of the camera lens whilst positioning your subject will affect the scaling factor of the Toolbox.

2. Click the **Scale** button on the Calibration window to enter pupil scale mode.

3. Hold the **Scale Calibration Stick** in front of the camera lens so that it is in the same vertical plane that the subject's eye was located, correctly focused and so one of the target dots appears in the centre of the Toolbox's camera window. The target being presented to the Toolbox should be focused by altering the distance between the calibration stick and the mirror. Do not adjust the camera's focusing ring.

   The camera window should now contain an image similar to Fig 15 below.

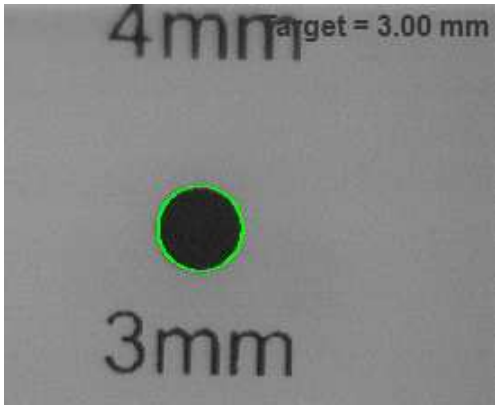

Fig 15. Tracking the Pupil Scale Calibration Stick

   Whilst a target on the calibration stick is centred in the camera window the Toolbox will track and measure it. Successful tracking is indicated by a green outline located around the circumference of the target. The current estimate for the size of the target will be displayed in the top right corner of the camera window. This value is calculated based upon the current scaling factor.

4. Move the Scale Stick so that it is focused on the number shown in the Pupil Target Diameter box (3mm by default). If you want to set the scale using a different size calibration dot, choose a different size from the drop down box labelled **Pupil**

Target Diameter located on the Calibration window. The value selected in this box should always be set to the same size as the target being tracked in the camera window[3].

Fig 16. Pupil Target Diameter Dropdown Box

5. Now click the **Apply** button to set the new scaling factor.

   The reported diameter of the target will now be identical, or very close to, the diameter of the target displayed in the camera window. Measuring the remaining targets on the calibration stick can be used as a method to check the accuracy of the calibration over a large range.

6. Click on the **Scale** button again to exit the pupil scale mode.

Subject Gaze Calibration

1. With the subject positioned correctly in the EyeLock headrest click the **Start** button on the Calibration window. A calibration target will appear on the stimulus display screen.

2. Instruct the subject to fixate on the target. The Toolbox will analyse all of the incoming images to identify a sequence of consistent pupil and Purkinje measurements.

3. Once the Toolbox is satisfied with the measurements it has collected the target will disappear and a new target will be displayed in a different location. This procedure will repeat itself until an entire sequence of targets has been displayed to the subject.

   Note: The Toolbox will not proceed to the next target until it has identified a consistent cluster of measurements. For this reason, it is important that the subject remains as still as possible during calibration.

[3] The size of a target is indicated underneath each target on the Scale Calibration Stick.

4. After the subject has worked through the complete set of calibration targets, the Toolbox will perform its internal calibration and present a second set of dots in the Calibration window (see Fig 17). The dots show the screen target positions, while the green lines show the relative positions where the system calculated the subject was actually looking. A good calibration is indicated by a set of short green lines. The following picture shows an example of a good calibration.

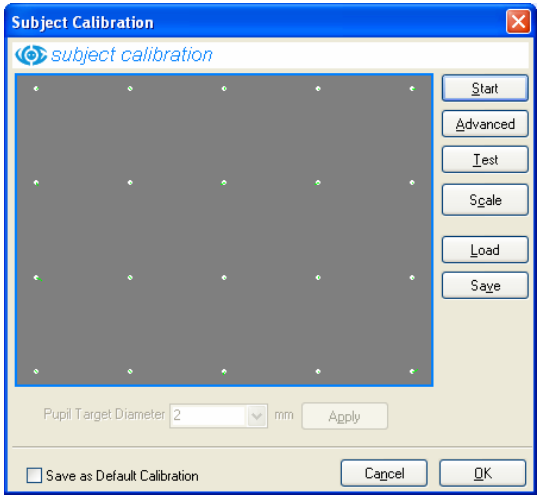

Fig 17. Successful Calibration

5. Sometimes during the calibration procedure the subject may focus on the wrong part of the display screen away from the target. If this happens you will see a large green line or a cluster of large green lines in one region of the Calibration window. You may also see smaller lines from surrounding targets being pulled in the opposite direction of the larger lines. See figure Fig 18.

   If this happens it is possible to select the individual targets that contain the largest errors for recalibration. To select the targets you want to represent, just left click on them with your mouse. The calibration procedure can now be repeated on these selected targets by clicking the **Start** button as before. **Note**: left-clicking on a selected target will deselect it.

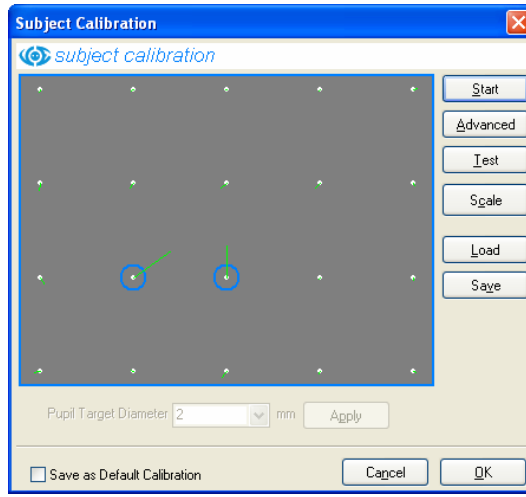

Fig 18. Calibration window illustrating two bad calibration targets that have been selected

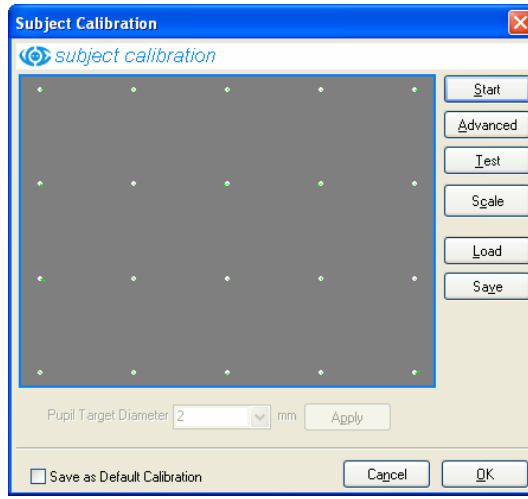

Fig 19. Calibration window illustrating the same calibration as above after the two targets have been re-calibrated

Sometimes when calibrating a subject it may be necessary to change the Toolbox's default settings. You may want to make it easier/harder for the subject to fixate on a target or try to match the conditions of the task that will be conducted by the subject after calibration. To do this you should click on the **Advanced** button to display the **Advanced Calibration Parameters** window as shown in Fig 20.

Using the options on this window it is possible to adjust the following characteristics. These settings are listed in the order that they appear on the window:

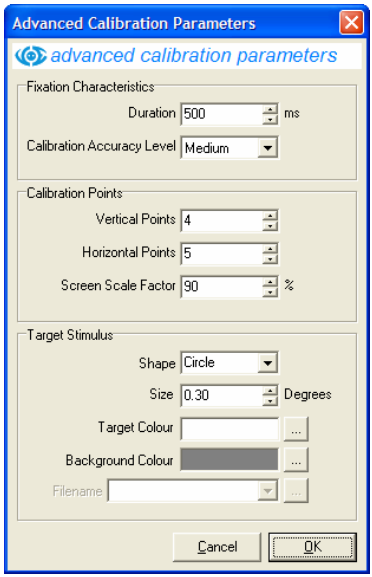

Fig 20. Advanced Calibration Parameters Window

- *Fixation Duration*. This sets the time period data is collected over when making pupil and Purkinje measurements. The larger this parameter the more frames will be used in the calculations and the longer the calibration procedure will take.

- *Calibration Accuracy level*. Allows you to adjust the tolerance the Toolbox uses when validating clusters of pupil and Purkinje measurements.

- *Vertical Points*. Calibration targets are arranged in a 2D array. This setting determines how many vertical locations are used to perform the calibration.

- *Horizontal Points*. Same as above except this setting specifies the number of horizontal elements used in the calibration. The total number of targets used for calibration is the product of these to settings.

- *Screen Scale Factor*. This parameter determines the percentage of the screen, originating from the centre that the targets will be displayed over. Setting this value to 100 would result in the targets covering 100% of the visible screen area. A setting of 50 would result in the targets covering 50% of the total screen area.

- *Shape*. Allows different shapes for the target to be selected. This setting also enables a bitmap image, such as a cartoon character, or face to be used as the calibration target

- *Size*. Sets the size of the calibration targets. This setting does not apply if a bitmap image has been selected as the target.

- *Target Colour*. Specifies the colour of the calibration targets. Again, this setting does not apply if a bitmap image is being used.

- *Background Colour*. Set the background colour that the targets are presented on.

- *Filename*. If a bitmap image has been selected in the Shape setting this parameter will become active and will allow you to browse/specify the bitmap file to be used as the calibration target.

Note: All of these parameters, except the parameters located in the Calibration Points group box, will be ignored if you have elected to use a non-computer based device as the presentation display. The appearance of this display and calibration targets are left entirely to the user when working with Custom Devices. Information regarding where targets should be displayed are returned in the Toolbox's **vetSetCallbackInitialiseDisplay**,

vetSetCallbackClearDisplay and **vetSetCallbackDrawTarget** event/call-back procedures.

The final aspects of the Calibration window are the **Test**, **Load** and **Save** buttons. The **Test** button can be clicked after the calibration procedure has been completed and, via visual feedback, can be used to test the accuracy of a calibration. In **Test** mode, the Toolbox will display a fixed set of 9 dots and will display the subject's calculated gaze position as a red dot in the Calibration window in real time.

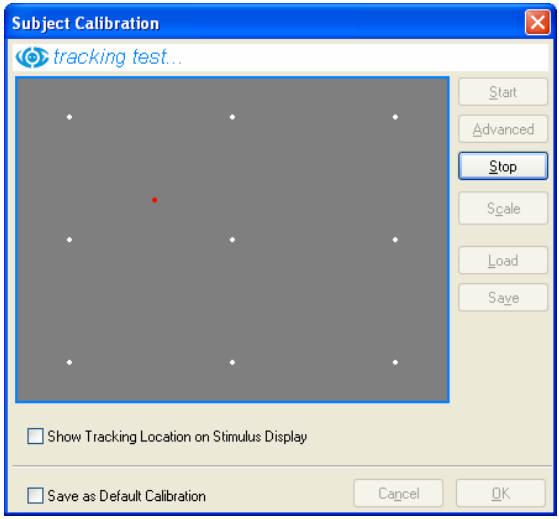

Fig 21. Calibration Window in Test Mode

The **Save** and **Load** buttons allow the calibration settings for a specific subject to be stored and retrieved at any time. The data is stored as a **.scf** Subject Calibration File which should remain accurate provided it is used by the same subject that created it and the viewing geometry has not been altered in any way. If in any doubt, the calibration procedure should be repeated.

The Toolbox will continue to use the current calibration settings until the end of the session or it is explicitly overwritten, either by loading a different calibration file or via recalibration.

Hardware states after Subject Calibration

CRS Visual Stimulus Generator

In order for the VSG to perform a subject calibration it is necessary for the Video Eyetracker Toolbox to draw targets onto some of the VSG's video pages. The Toolbox also needs to modify the VSG's palette and may change global settings such as the spatial units and colour space that are being used.

The following section describes the state of a VSG after a subject calibration has been performed using the Video Eyetracker Toolbox with the CRS Toolbox for MATLAB. For ease of use we recommend that you try to draw and define your presentation stimuli after you have run a subject calibration, or if this is not possible then you should be aware that some of the video pages that your presentation stimulus appears on may be corrupted or cleared and that the spatial units, colour spaces and Object Animation System objects you have previously defined may also need to be reset.

- The first and second video pages will be cleared using pixel level 254 (CRS.BACKGROUND)
- The Object Animation System (OAS) will be turned off
- All (OAS) objects created prior to running a subject calibration will be destroyed
- Overlay pages will not be visible
- Spatial units will be set to CRS.PIXELUNIT
- The top left corner of video memory space will be set to (0, 0)
- The drawing origin will be set to the centre of the screen.
- The active colour space will be set to CRS.CS_RGB
- The draw mode will be set to CRS.CENTREXY

- Any page cycling entries and stored LUTs should be considered lost

Dual VGA

Video Eyetracker Toolbox creates a separate window to display the calibration targets. This window is then destroyed after subject calibration has been completed. Consequently, it is not necessary to reset the stimulus window after calibration.

Custom Device

The Toolbox has no direct influence over the state of custom devices that are used with it. Cleaning up of the display after Calibration is left entirely to the responsibility of the user.

videoEyetrace

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Overview

It is important to remember that the software component of the Video Eyetracker Toolbox is implemented to enable eye tracking functionality to be accessed and controlled from MATLAB or any Windows programming tool that supports Microsoft COM. However, for completeness and ease of use, the Toolbox is also supplied with an example application called videoEyetrace, which demonstrates the Toolbox's functionality in a ready to use form.

The videoEyetrace Window

Start videoEyetrace by clicking on the videoEyetrace icon, or via the Windows **Start** menu. The main window provides a ready-made user interface for the Toolbox (see Fig 22 below). The buttons on the menu bar and tool bar are used to control the type of stimulus displayed, how the data is collected and how the test subject is calibrated.

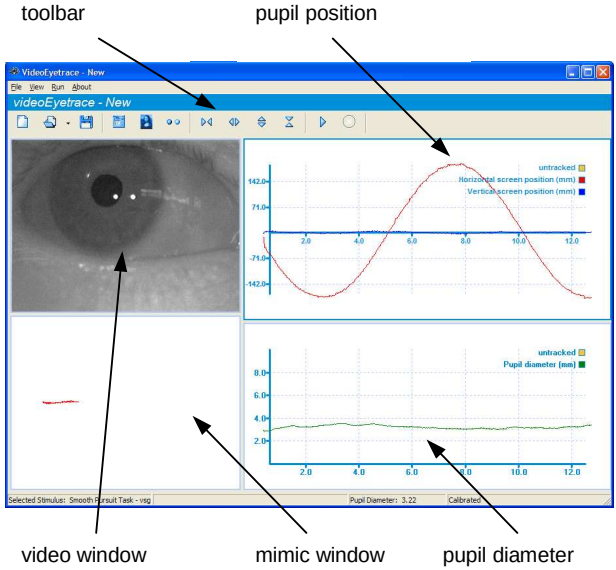

Fig 22. videoEyetrace Main Window

Initialising the Video Eyetracker Toolbox Camera

videoEyetrace is designed to work with the whole Video Eyetracker Toolbox family, as well as pre-recorded video .cam files. Use the **Select Video Source** option from the **File** menu to reveal the following window:

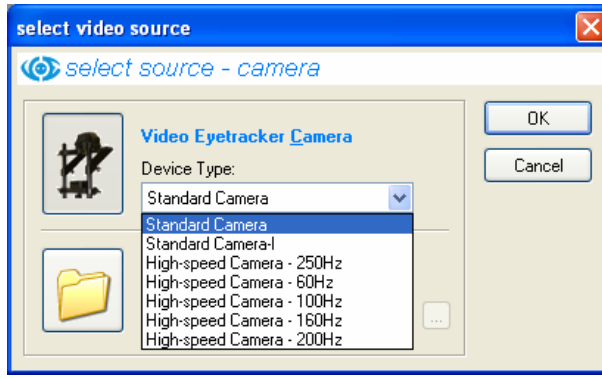

Fig 23. Select Video Source Window

The EyeLock icon allows you to select between the different cameras and their range of sampling frequencies. If you are running a 50 Hz system, and your camera was shipped with a Camera-I label, select **Standard Camera-I** as you are running an interlaced video camera. If there is no label, select **Standard Camera** as your camera is running in progressive scan mode. If you have purchased the High-Speed system, select one of the **High-speed Camera** options as shown in Fig 23.

Alternatively, if you wish to perform eye tracking on an existing video .cam file, select the folder icon and use the browse button to locate the relevant file.

Title bar

The Title bar displays the program control icon, the application and active protocol names, and the minimise, maximise and close buttons.

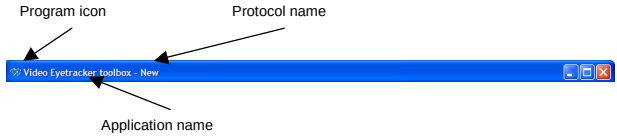

Fig 24. Title Bar

Menu bar

The Menu bar displays the headings that lead to the menu controls. These menu controls are permanently available with the exception of the Save tab which is disabled if the current data has already been saved. As with most Windows programs, the menu buttons are grouped together depending upon their functionality and organised under more generic menu headings.

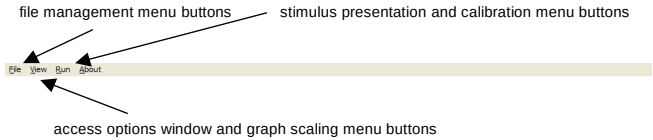
file management menu buttons
stimulus presentation and calibration menu buttons
File View Run About
access options window and graph scaling menu buttons

Fig 25. Menu Bar

Toolbar

The tool bar contains buttons that duplicate the functions of the more frequently used menu options. The main purpose of the tool bar is to provide quick and easy access to these menu controls.

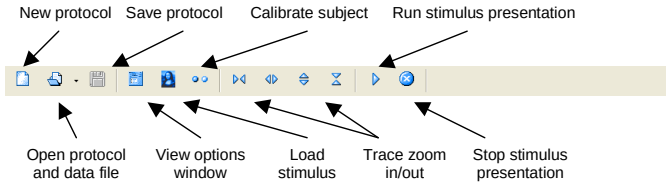

Fig 26. Toolbar

Data windows

videoEyetrace outputs eye tracking results using two data windows. The upper data window outputs the tracked eye positions in graphical form using the horizontal axis to represent time and the vertical axis to represent eye position. During tracking, the graph displays two traces showing how the horizontal and vertical components of eye position vary with time. Untracked sections caused by blinking or looking outside the legitimate viewing range are denoted by a yellow trace superimposed on the horizontal time axis.

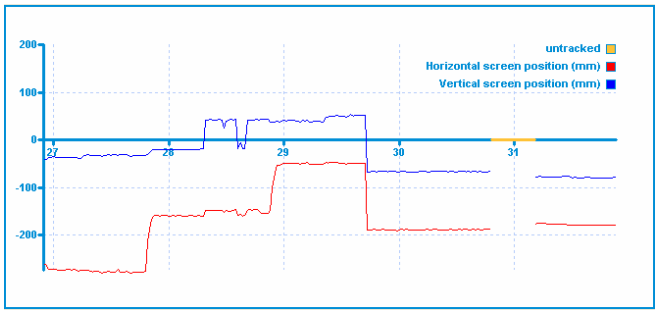

Fig 27. videoEyetrace Eye Tracking Graph

The lower data window, which shares the same horizontal time axis, plots the calculated pupil width for each tracked frame plus a digital input trace if timing signals are used.

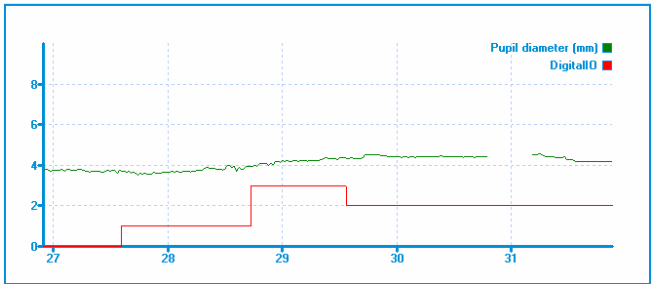

Fig 28. videoEyetrace Pupil Diameter and Digital IO Graph

During tracking, both graphical outputs will automatically scroll forwards and can be zoomed in or out, either horizontally or vertically, using the following toolbar icons:

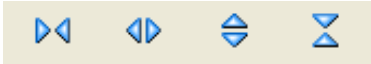

Fig 29. Zoom Icons

Status bar

The Status bar displays information about videoEyetrace. The first section of the status bar displays the name of the currently selected stimulus and the second section displays the name of the data file currently being shown on in the data window. The second section of the status bar will stay empty until either data has been collected or a data file has been opened.

Fig 30. Status Bar

Changing Stimuli and Settings

The presentation stimulus can be controlled or modified using the **Stimulus** window. This can be accessed by either clicking on the Mona Lisa icon on the Toolbar or by clicking **View|Stimulus** from the Menu bar.

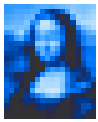

Fig 31. videoEyetrace Stimulus Icon

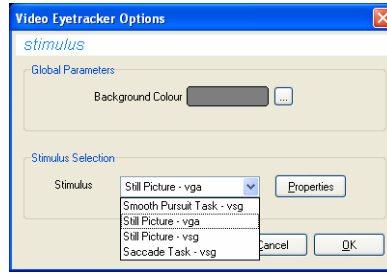

Fig 32. videoEyetrace Stimulus Window

The window shown in Fig 32 controls the type of stimulus presented to the subject. The currently selected stimulus is displayed in the stimulus combo box located in the Stimulus Selection area of the tab. Different stimuli can be chosen by clicking on the down arrow to the right of the combo box and selecting a new stimulus from the list. Fig 32 shows that there are 3 stimulus options available if you are using a VSG and a Still Picture option if you are in dual VGA mode.

Once the required stimulus has been selected its parameters can be edited by clicking on the **Properties** button to the right of the Stimulus combo box. The background colour used for the stimuli is displayed in the colour panel (remember this colour is not gamma corrected) and can be edited by either double clicking in the colour panel or clicking on the browse button to the right of the panel.

Changing View Options

Click on the View Options icon on the toolbar:

Fig 33. videoEyetrace View Options Icon

to display the window shown in Fig 34:

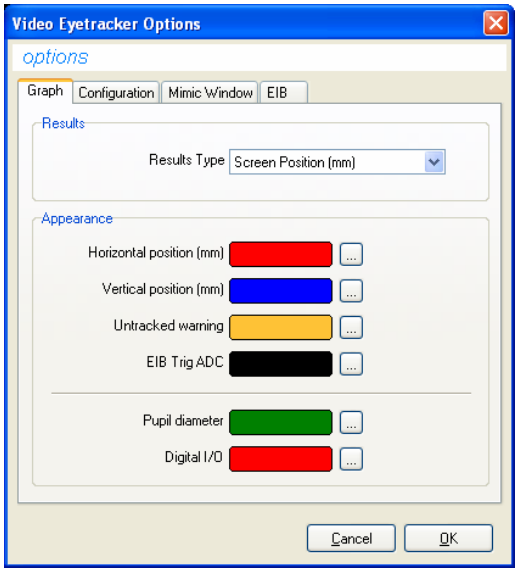

Fig 34. Video Eyetracker Options – Graph Tab

Once the stimulus has been selected, the Options window contains everything else necessary to configure your experimental setup. This window has four different tabs: **Graph, Configuration, Mimic Window** and **EIB.**

Graph Tab

Clicking on the Graph tab (see Fig 34) will reveal the following options.

The **Results** sub window allows videoEyetrace to return the viewed screen position either in millimetres or in Fick or Helmholtz angle co-ordinates (see Appendix F for further details). The **Appearance** sub window displays the current settings for all graphical traces which can be customised by clicking on the appropriate browse icons. The **EIB Trig ADC** input trigger trace is

only available for the High-Speed system. See page 54 for further details.

Configuration Tab

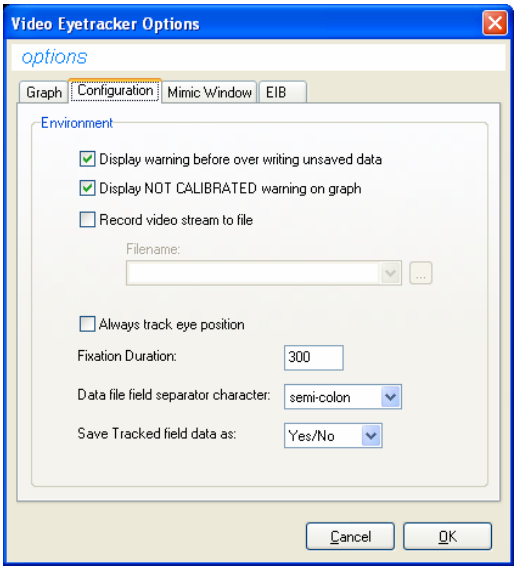

Fig 35. Video Eyetracker Options – Configuration Tab

The Configuration tab displays a set of configuration settings covering visual warnings and the option to record the video stream to file. In addition, you can control the minimum duration necessary to identify a fixation and choose the type of field separator in the results data file. The last option box controls whether the tracked status in each image is recorded in the results file as either an alphabetic “Yes-No” or binary “1-0” format.

Mimic Tab

The Mimic tab controls how the measured eye tracking trace is presented in the Mimic window. The top dialog box controls the

amount of time that the trace will persist before disappearing. This is set, by default, to 5 seconds duration but can be altered accordingly. The second dialog box controls whether the trace should persist with constant or fading intensity for the prescribed duration.

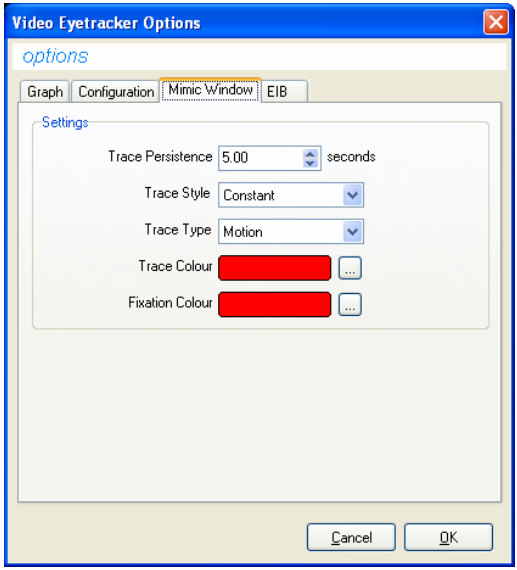

Fig 36. Video Eyetracker Options – Mimic Tab

The third box controls the type of information to be plotted on the Mimic window. This can be set to map out eye motion, eye fixations, or both. Eye fixations are represented as circles where the centres represent eye position and the radii represent duration. The last 2 boxes control the motion trace and fixation colours.

EIB Tab (High-Speed System only)

The EIB tab allows you to configure the High-Speed Eyetracker Interface Box. The first sub-window allows you to disable the LEDs on the Eyetracker Interface Box front panel if, for example, their light output could possibly interfere with the experiment. The

second sub-window controls the signal output for the detected eye position. This can be either 0.01 volts per mm, 0.001 volts per mm, or 0.1 volt per degree in either Fick or Helmholtz angular co-ordinates.

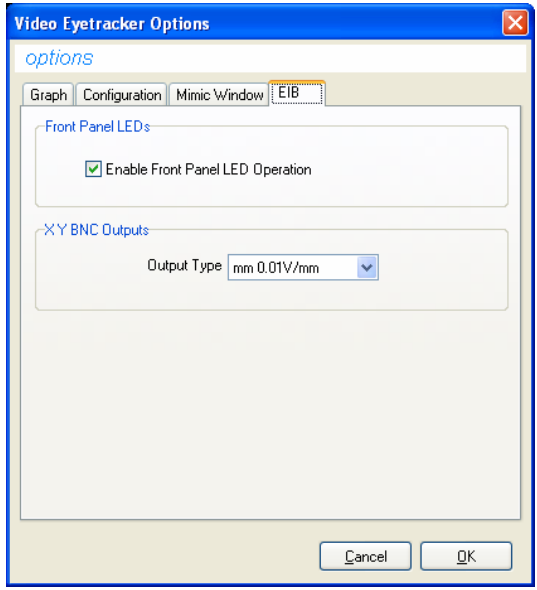

Fig 37. Video Eyetracker Options – EIB Tab

Eye Tracking

Once the calibration procedure is complete and a stimulus has been loaded, press the Run icon on the Toolbar to enter tracking mode:

Fig 38. Run Icon

This will initiate tracking and output the results in the graph window in real time. A typical graph output for a sinusoidal smooth pursuit task is shown in Fig 39:

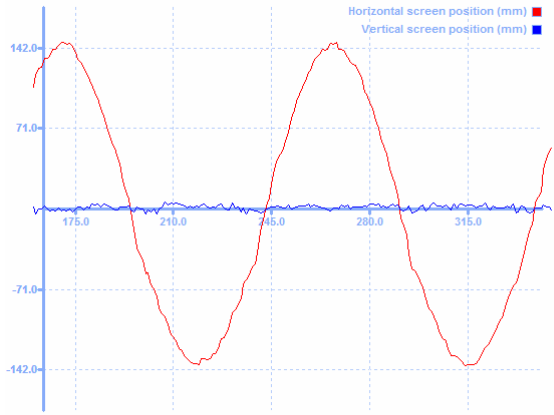

Fig 39. Smooth Pursuit Task

The horizontal axis represents time in seconds while the vertical axis represents eye gaze screen position in millimetres. In this example, the target was moving horizontally which is indicated here by the sinusoidal red (horizontal) trace while the vertical (blue) trace represents biological and system noise.

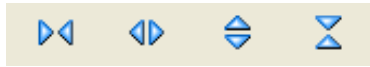

Fig 40. Graph Zoom Icons

The horizontal and vertical scales of the output graph can be changed before, during or after tracking using the above icons available on the main toolbar.

During tracking, videoEyetrace will also project the recent eye positions into the mimic window and will detect and display any fixations as circles with radii proportional to their duration. A typical example of this is shown in Fig 41

Fig 41. Mimic window showing locus of tracked eye positions and fixations

During tracking, the Toolbox is able to accommodate fast eye rotations, sudden head movement and changes in pupil size. By imaging in the infrared, it is also relatively immune to changes in ambient illumination and can accommodate a wide range of spectacles or contact lenses. The system is intelligent enough to know whether or not an eye is present in the video images. This subject is therefore free to blink or take breaks between eye tracking tests, if necessary, without the need to recalibrate each time. The system can return eye position in Fick, Helmholz or screen position in millimetres and will automatically return “Not Tracked” if it detects that an eye is not present in the video image.

videoEyetrace will automatically terminate saccade, smooth pursuit or bitmap image tasks at the end of their defined duration. Alternatively, any eye tracking task can be terminated using the stop icon on the main toolbar:

Fig 42. Stop Icon

Saving and Loading

videoEyetrace can save and load Data files. These can be saved and opened either via the **File** menu or the **Save** and **Open** buttons on the toolbar.

Data Files (*.ved)

The default videoEyetrace data files are text files containing all the results collected from an eye tracking experiment. The header section summarises the experiment in terms of the type of stimulus used and the duration of the experiment. The header section also states the position of the first line of tracked eye position and pupil diameter data. This results data is delimited so that it may be readily imported into an Excel worksheet, as shown below.

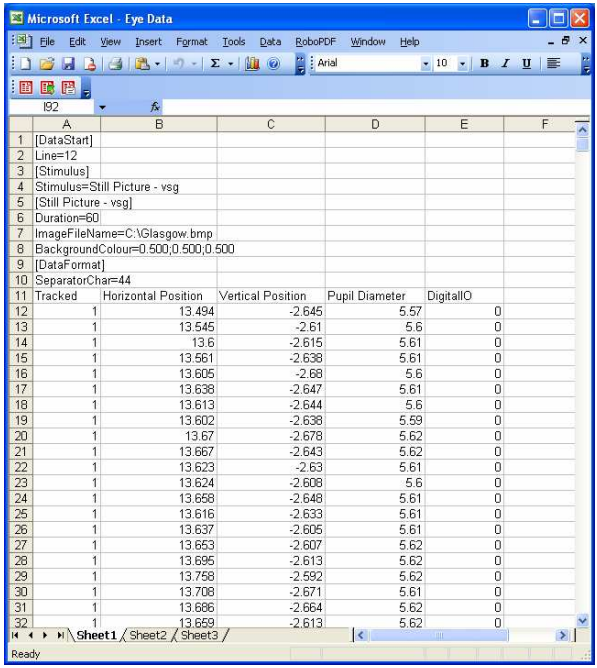

Fig 43. Results Data File

Custom Results Data File (*.ved)

The custom data file option, available from the **File** menu, can be used to deselect any of the default file entries shown in Fig 43. It also provides an option to modify the field separator character and include a time field, if required. This field is expressed in milliseconds and starts at zero for the first results data entry. Temporal quantisation is dependant on the sampling rate of your Selected Video Source.

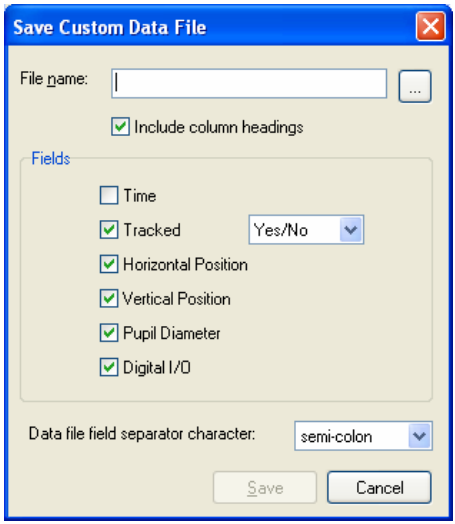

Fig 44. Custom Data File Options Window

MATLAB Data File (*.mat)

The results data file can also be saved as a MATLAB .mat format from the File menu.

Mimic Image (*.bmp)

The Mimic image window, complete with mimic trace, can be saved as a Bitmap image from the File menu.

Communicating with the Toolbox

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Synchronisation – 50 Hz Systems

The cable supplied with your Video Eyetracker Toolbox terminates with a 9 pin D-type connector and a 25 pin D-type connector. The 9 pin connector attaches to the Picolo frame grabber and the 25 pin connector to a **Digital I/O** port on either a VSG2/5 Feature Connector or a ViSaGe as shown in Fig 45

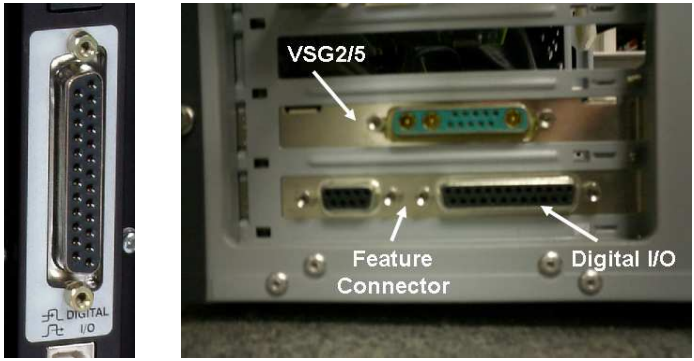


Fig 45. 25 pin Digital I/O on ViSaGe (Left) and VSG2/5 (Right)

Note: It is not necessary to connect the 25 pin D-type end of the cable unless you are planning to synchronise the data collected by the Toolbox with your stimulus presentation system.

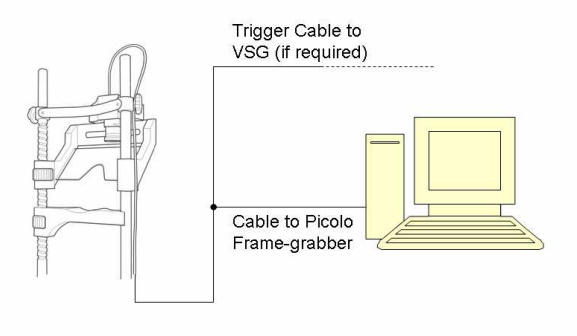


Fig 46. Cable Connections for Triggering

The Toolbox's video capture card has four digital I/O lines. The first three (least significant) of these lines are set as input lines and their states are read every frame. Thus, it is possible to feed in three independent signals that will be read by the Toolbox every frame. In order to guarantee that your trigger values are read by the Toolbox they should last for at least a frame length as the Toolbox only samples the lines once every frame[4]. If you are using a VSG, it is advisable to create stepped, rather than pulsed, triggers which are only modified when the stimulus changes. (See the Library Topics section on Triggering in the Documentation supplied in your vsgDesktop for further details.)

The combined values for these three lines are returned to your program as the **DigitalIO** parameter in the data set for each frame. Fig 47 displays the possible values for this parameter and the corresponding states of the three channels.

DigitalIO Value	Channel State Line 2	Line 1	Line 0
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

Fig 47. Combined Digital I/O Values

The fourth digital I/O line is an output trigger. This line is set high whilst the Toolbox is tracking and low when the Toolbox is not tracking. Fig 48 describes the inter-connections for the four digital I/O lines between the 25-way D-type connector and the digital I/O lines of a ViSaGe or VSG2/5.

[4] When changing the state of a line it is good practice to allow for a transition period so that it becomes impossible for a line to be read at the precise moment that it is being set.

Digital I/O Line	Pin on 25-way D-type Connector	ViSaGe or VSG2/5 I/O Line
0	7	DOUT 6
1	8	DOUT 7
2	9	DOUT 8
3	21	DIN 7

Fig 48. Digital I/O Pin-Out Details

Synchronisation – High-Speed Systems

Eyetracker Interface Box -- Inputs

The High-Speed system must be used in conjunction with the Eyetracker Interface Box (EIB). Details of how to connect this are available in the Hardware Installation section of the High-Speed Video Eyetracker Toolbox Installation Manual.

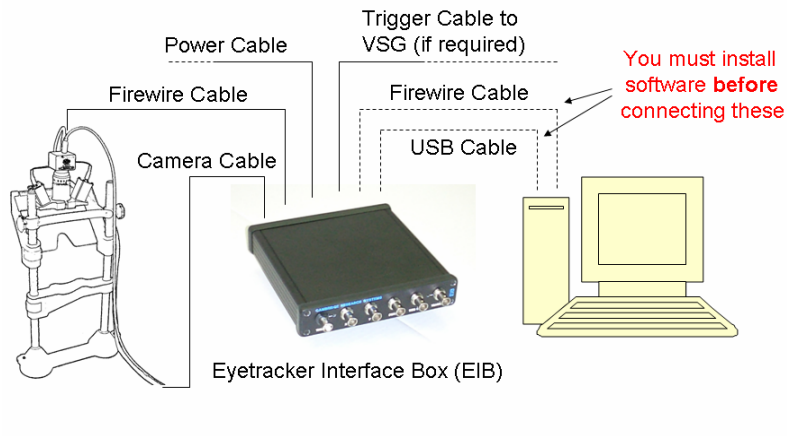


Fig 49. Connections to Camera, EIB and PC

CRS ViSaGe

To receive digital timing triggers, the High-Speed system requires a trigger cable connecting from the **Digital Trig** port on your EIB (see Fig 51) to the 5 pin **Accessory** connector on your ViSaGe (see Fig 50). This frees up ViSaGe's 25 pin digital IO port for use with, for example, an EEG system.

Fig 50. Accessory Connector on ViSaGe

The trigger signals are transmitted from the EIB via its USB port to the PC where it is logged in the **DigitalIO** column of the videoEyetrace results file, and the **digitalIO** field in the MATLAB **Data** structure (see Appendix G for further details). However, unlike the 50 Hz system, the High-Speed version does not output a digital tracking signal to the VSGs Digital Input line 7 but is instead output on the **Tracked** BNC connector (see Fig 53).

Fig 51. Eyetracker Interface Box – Rear Panel

The High-Speed system can accept an input trigger from other external devices via the **Trig In** BNC connector on the EIB front panel (see Fig 53). This input can be a TTL or analogue voltage signal within the range of ±5 volts. In the MATLAB **Data** results structure, the values are returned in the **trigIn** field and are in the range of ±1. This input also appears in videoEyetrace as the **EIB Trig ADC** graphical plot and is also logged as part of the **.ved** results data file.

CRS VSG 2/5

The High-Speed system can receive digital timing triggers from a VSG2/5 visual stimulus generator. The supplied trigger cable connects from the **Digital Trig** port on your EIB (Fig 51) to the 25 pin **Digital I/O** port on your Feature Connector (Fig 52) or BNC Breakout Box. This input can also be three TTL digital voltage signals (0 or 5 volts).

The trigger signals are transmitted from the EIB via its USB port to the PC where it is logged in the **Digital I/O** column of the videoEyetrace results file, and the **digitalIO** field in the MATLAB **Data** structure (see **Appendix G** for further details). However, unlike the 50 Hz system, the High-Speed version does not output a digital tracking signal to the VSG's Digital Input line 7 but is instead output on the Tracked BNC connector (see Fig 53).

The High-Speed system can accept an input trigger from other external devices via the **Trig In** BNC connector on the EIB front panel (see Fig 53). This input can be a TTL or analogue voltage signal within the range of ±5 volts. In the MATLAB Data results structure, the values are returned in the **trigIn** field and are in the range of ±1. This input also appears in videoEyetrace as the **EIB Trig ADC** graphical plot and is also logged as part of the **.ved** results data file.

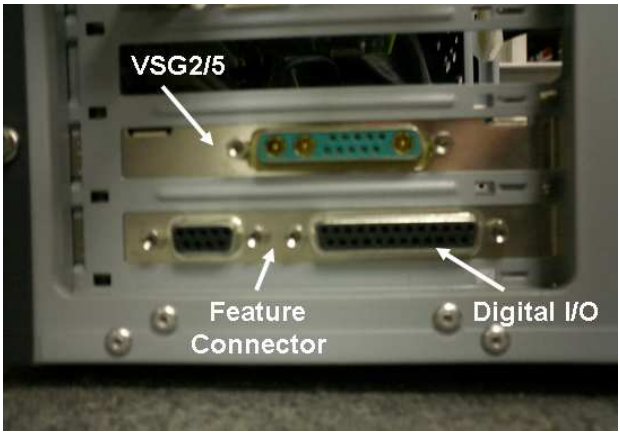


Fig 52. 25 pin Digital I/O on VSG2/5

Eyetracker Interface Box -- Outputs

Fig 53. Eyetracker Interface Box – Front Panel

Apart from the **Trig IN** BNC, the other BNC connectors output the recorded eye position data which can then be logged using external equipment. The **Pupil** output is statically scaled at 0.1 volts per mm of pupil diameter. **Trig Out** replicates any signal fed into **Trig In** and **Tracked** outputs a standard TTL signal of either 0 or approximately 5 volts. The scales of the **X** and **Y** outputs can be set using the **vetSetEIB_XYOutputType** command which is detailed in Appendix A (or within videoEyetrace under the EIB tab of Graph Options).

Video Eyetracker Toolbox and MATLAB

MATLAB is a data analysis and visualisation application built around a simple scripting language and is widely used in the creation of models and in the analysis of experimental results. By providing tools to help the vision researcher control and analyse their experiments from a single environment, we hope to reduce the training burden on new entrants to the field, as well as making it easier for existing experimenters to integrate their experimental design and control with their theoretical modelling and analysis.

The Toolbox's open interface design allows you to integrate eye tracking functionality with your existing laboratory software or write new eye tracking applications using a familiar environment. Because the Toolbox has been designed in this way, all aspects of its eye tracking functionality can be accessed and controlled from MATLAB or any windows programming tool that supports Microsoft COM.

In particular, MATLAB's relatively simple and concise scripting environment has gained a widespread following among the vision research community. As a result, MATLAB is now the default software environment for which Cambridge Research Systems provides support. What follows are two worked examples which demonstrate the simplicity of using the Video Eyetracker Toolbox from within MATLAB.

The commands that make up the Video Eyetracker Toolbox interface for MATLAB are detailed in **Appendix A**. If you want to use a different programming tool, you will find more information about the COM interface in the CRS Support Portal (www.crsltd.com/support/login).

Worked MATLAB Eye Tracking Examples

The MATLAB scripts discussed in this section are distributed with the CRS Toolbox for MATLAB which should be downloaded from the Cambridge Research Systems Support Portal (www.crsltd.com/support/login) as described in Appendix A.

Example 1: Bitmap Stimulus with Dual VGA

Example 1 is designed to demonstrate basic eye tracker functionality in a Dual VGA configuration and is suitable for use with the 50 Hz and High-Speed systems. This example displays a single bitmap image, calibrates your subject, tracks subsequent eye positions for 30 seconds, displays the results and finally saves the collected data to a file.

This demonstration does not require a CRS Visual Stimulus Generator (VSG) but assumes you are using a dual Windows display configuration with the Primary output set to your Windows desktop monitor and the Secondary output set to display the visual stimulus. See the **Dual VGA** section in the **Calibration** Chapter for further details.

Run the demoVET_simpleVGAstimulus.m script. The following lines of code initialise the Video Eyetracker Toolbox system and the stimulus display device:

```
function demoVET_simpleVGAstimulus

% Declare CRS MATLAB constants
global CRS;
if  isempty(CRS); crsLoadConstants; end;

% Set the stimulus device to Dual-VGA.
%(For use with a VSG, use the constant CRS.deVSG)
vetSetStimulusDevice(CRS.deVGA);

% Ask the user to select a video source
errorCode = vetSelectVideoSource(CRS.vsUserSelect);
if(errorCode<0); error('Video Source not selected.');
end;
```

… which will open the window shown in Fig 54

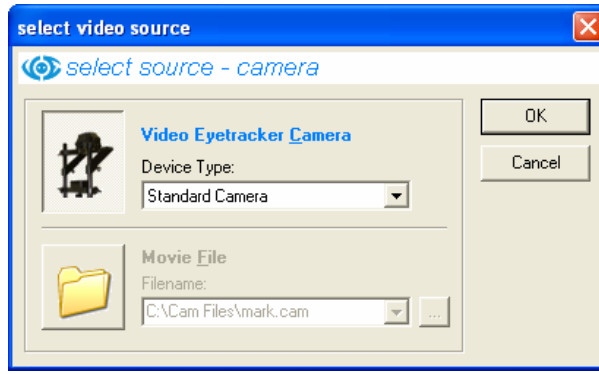


Fig 54. Camera / Movie File Source Window

Select the Video Eyetracker Camera which corresponds to your supplied system from the Device Type drop down box. This option should be highlighted as shown in Fig 54, but if not, click the EyeLock button to its left. You can select from Standard Camera, Standard Camera-I or one of the High-Speed options. Once the correct camera has been selected, click **OK** to run the following lines of code which open up the Camera, and Calibration windows:

```
% Create a live camera screen so that we can position
% the camera to image the test subject's eye

vetCreateCameraScreen;
```

```
% Calibrate the subject, and return if
% the user exits before completion.

errorCode = vetCalibrate;
if(errorCode<0); error('Calibration not completed.');
end;

% Clear the VET VGA calibration window.

vetSetDeviceParameters(CRS.deUser);
```

Once your subject is correctly positioned, click **Start** in the Calibration window. The calibration routine will now proceed by requesting the test subject to fixate on a number of calibration targets on the stimulus monitor:

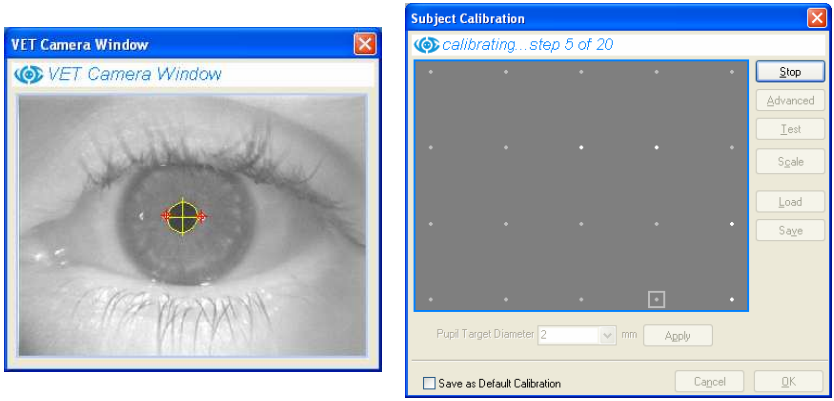


Fig 55. Live Camera and Calibration Windows (Calibration in Progress)

Once calibration is complete, click **OK** in the subject Calibration window. The following lines of code will check that Windows has been configured in dual VGA mode and calculate both monitor positions.

```
% Check we have dual-VGA monitor setup
% Calculate primary and secondary monitor positions.

MonitorPos         = get(0, 'MonitorPosition');
if(numel(MonitorPos)<8); error('Less than two monitors
detected.'); end;
```

```
PrimaryPos          = MonitorPos(1,:);
SecondaryPos        = MonitorPos(2,:);
PrimarySize         = [PrimaryPos(3) - PrimaryPos(1),
PrimaryPos(4) - PrimaryPos(2)] + 1;
SecondarySize       = [SecondaryPos(3) -
SecondaryPos(1),SecondaryPos(4)-SecondaryPos(2)] + 1;
PrimaryLowerLeft    = [PrimaryPos(1),
((SecondarySize(2) - PrimaryPos(2))
 - PrimarySize(2)) + 2];
SecondaryLowerLeft = [SecondaryPos(1),
((PrimarySize(2)    - SecondaryPos(2)) -
PrimarySize(2)) + 2];
```

The following lines of code will then display the dialogue box as shown in Fig 56 and await a user response

```
% Display a dialog to select the stimulus display.
MonitorToUse = uigetpref('Monitors','One',...
          'Stimulus Monitor Selection Dialog',...
          'Select which monitor to use.',{'1','2'},...
          'CheckboxString','Always use this monitor.');

switch MonitorToUse;
case '1'
    SelectedPos = [PrimaryLowerLeft,  PrimarySize  ];
case '2'
    SelectedPos = [SecondaryLowerLeft,SecondarySize];
end
```

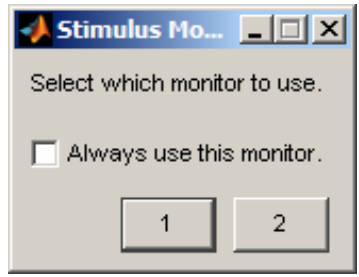


Fig 56. Select Stimulus Monitor

Select the appropriate monitor by clicking the relevant button. The following lines of code will now display the stimulus image on the chosen stimulus monitor:

```
% Pick a stimulus image, and get the full path to the
% file. (The image file must be on your MATLAB path).
ImageFile = which('Glasgow.bmp');

% Read the selected image file, getting both the image
% and the palette data.
[Image,Palette] = imread(ImageFile);

% Create a figure window to display the stimulus
% Load the bitmap image onto the selected monitor,
% scaling appropriately.
Figure1Handle = figure(1); AxesHandle = axes;
set(AxesHandle,  'Position', [0 0 1 1]);
set(Figure1Handle, 'MenuBar',
'none','ToolBar','none','Position',SelectedPos);
imagesc(Image);
colormap(Palette);
axis('off');
```

The same stimulus image will now be loaded onto a Mimic screen on your Windows monitor:

```
% Create Mimic Screen and load Bitmap image
vetCreateMimicScreen;
vetSetMimicScreenDimensions(400, 0, 400, 300);
vetSetFixationPeriod(300);
vetSetFixationRange(10);
vetSetMimicPersistenceType(CRS.ptMotionAndFixations);
vetLoadBmpFileToMimicScreen(ImageFile,1);
```

Notice that the Mimic screen has been set to show any fixations which last for at least 300 milliseconds within a 10mm cluster. The Toolbox will now track for 30 seconds. All eye movements and fixations will be output to the Mimic window as shown in Fig 57:

```
% Track for 30 seconds, then stop tracking
vetClearDataBuffer;
vetStartTracking;
pause(30);
vetStopTracking;

% Tidy up by clearing away camera and mimic screens.
vetDestroyCameraScreen;
vetDestroyMimicScreen;
close(figure1Handle);
```

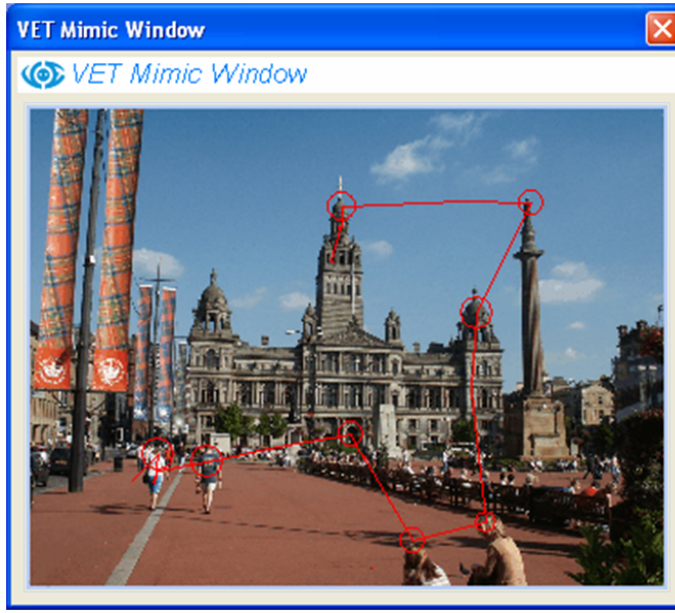


Fig 57. Mimic Window with Motion and Fixations Trace

The tracked results will now be plotted in Fick angular coordinates with longitude in blue and latitude in red. Some example results are shown in Fig 58

```
% Retrieve the recorded eye positions
% without removing them from the buffer.
Remove = false;
DATA = vetGetBufferedEyePositions(Remove);


% Display the retrieved positions
figure(2); cla; hold on;
plot(DATA.fickPositions(:,1),'b'); %Longitude in blue
hold on;
plot(DATA.fickPositions(:,2),'r'); %Latitude in red
grid on;
```

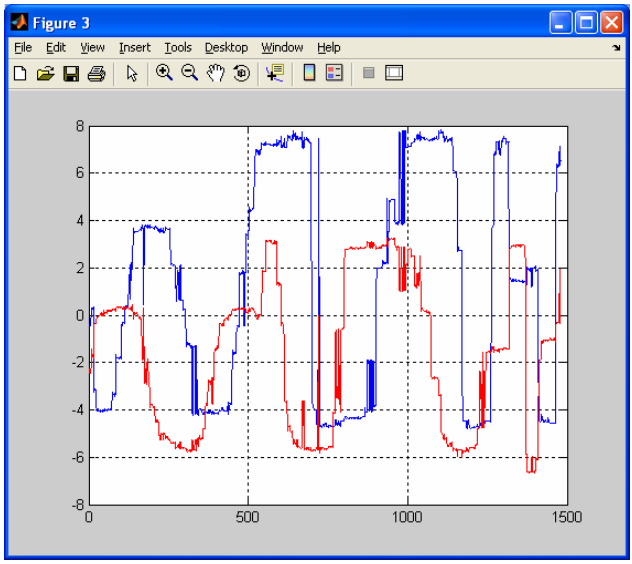


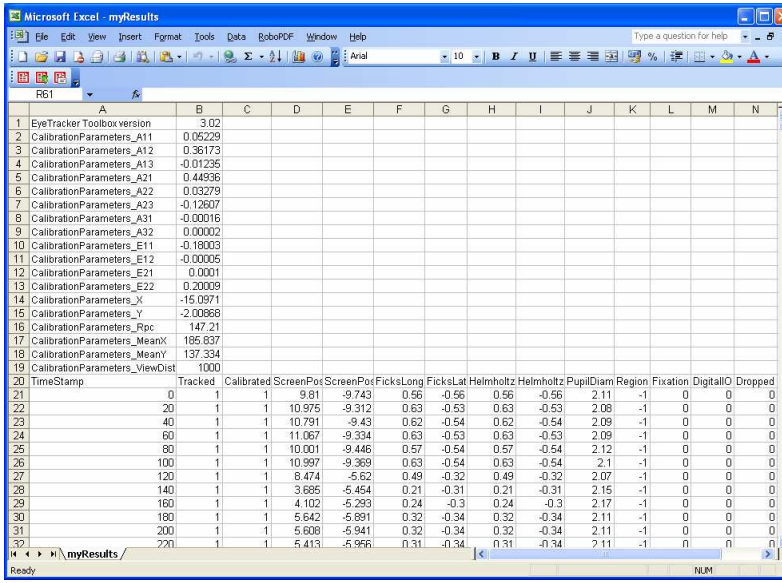
Fig 58. Tracked Eye Data in Fick Angular Co-ordinates

Finally, the results are saved to disk and the eye position data buffer is then deleted:

```
% Save the results to disk as a comma delimited file.
CurrentDirectory = cd;
tempfile = [CurrentDirectory,'\myResults.csv'];
vetSaveResults(tempfile, CRS.ffCommaDelimitedNumeric);

% Clear the data buffer.
vetClearDataBuffer;
```

This will create a comma delimited results data file which can be imported into other applications. Fig 59 shows the data when it has been imported into Microsoft Excel. You can see all the calibration parameters plus the full eye tracking results for every processed image:



Microsoft Excel - myResults

File Edit View Insert Format Tools Data RoboPDF Window Help

R61

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	EyeTracker Toolbox version	3.02												
2	CalibrationParameters_A11	0.05229												
3	CalibrationParameters_A12	0.36173												
4	CalibrationParameters_A13	-0.01235												
5	CalibrationParameters_A21	0.44936												
6	CalibrationParameters_A22	0.03279												
7	CalibrationParameters_A23	-0.12607												
8	CalibrationParameters_A31	-0.00016												
9	CalibrationParameters_A32	0.00002												
10	CalibrationParameters_E11	-0.18003												
11	CalibrationParameters_E12	-0.00005												
12	CalibrationParameters_E21	0.0001												
13	CalibrationParameters_E22	0.20009												
14	CalibrationParameters_X	-15.0971												
15	CalibrationParameters_Y	-2.00868												
16	CalibrationParameters_Rpc	147.21												
17	CalibrationParameters_MeanX	185.837												
18	CalibrationParameters_MeanY	137.334												
19	CalibrationParameters_ViewDist	1000												
20	TimeStamp	Tracked	Calibrated	ScreenPos	ScreenPos	FicksLong	FicksLat	Helmholtz	Helmholtz	PupilDiam	Region	Fixation	DigitalIO	Dropped
21	0	1	1	9.81	-9.743	0.56	-0.56	0.56	-0.56	2.11	-1	0	0	0
22	20	1	1	10.975	-9.312	0.63	-0.53	0.63	-0.53	2.08	-1	0	0	0
23	40	1	1	10.791	-9.43	0.62	-0.54	0.62	-0.54	2.09	-1	0	0	0
24	60	1	1	11.067	-9.334	0.63	-0.53	0.63	-0.53	2.09	-1	0	0	0
25	80	1	1	10.001	-9.446	0.57	-0.54	0.57	-0.54	2.12	-1	0	0	0
26	100	1	1	10.997	-9.369	0.63	-0.54	0.63	-0.54	2.1	-1	0	0	0
27	120	1	1	8.474	-5.62	0.49	-0.32	0.49	-0.32	2.07	-1	0	0	0
28	140	1	1	3.685	-5.454	0.21	-0.31	0.21	-0.31	2.15	-1	0	0	0
29	160	1	1	4.102	-5.293	0.24	-0.3	0.24	-0.3	2.17	-1	0	0	0
30	180	1	1	5.642	-5.891	0.32	-0.34	0.32	-0.34	2.11	-1	0	0	0
31	200	1	1	5.608	-5.941	0.32	-0.34	0.32	-0.34	2.11	-1	0	0	0
32	220	1	1	5.413	-5.956	0.31	-0.34	0.31	-0.34	2.11	-1	0	0	0

myResults

Ready NUM

Fig 59. MATLAB Eyetracking Results Data File

The full code listing for this MATLAB example is as follows:

```
function demoVET_simpleVGAstimulus

% ------------------------------------------------------
% This demonstrates the most basic functionality of
% the Video Eyetracker Toolbox.

% ------------------------------------------------------

% Declare CRS MATLAB constants
global CRS;
if  isempty(CRS); crsLoadConstants; end;

% Set the stimulus device to Dual-VGA.
%(For use with a VSG, use the constant CRS.deVSG)
vetSetStimulusDevice(CRS.deVGA);

% Ask the user to select a video source
errorCode = vetSelectVideoSource(CRS.vsUserSelect);
```

```
if(errorCode<0); error('Video Source not selected.');
end;

% Create a live camera screen so that we can position
% the camera to image the test subject's eye

vetCreateCameraScreen;

% Calibrate the subject, and return if
% the user exits before completion.

errorCode = vetCalibrate;
if(errorCode<0); error('Calibration not completed.');
end;

vetSetDeviceParameters(CRS.deUser);

% Check we have dual-VGA monitor setup
% Calculate primary and secondary monitor positons.

MonitorPos         = get(0, 'MonitorPosition');
if(numel(MonitorPos)<8); error('Less than two monitors
detected.'); end;
PrimaryPos         = MonitorPos(1,:);
SecondaryPos       = MonitorPos(2,:);
PrimarySize        = [  PrimaryPos(3)-  PrimaryPos(1),
PrimaryPos(4)-  PrimaryPos(2)] + 1;
SecondarySize      = [SecondaryPos(3)-
SecondaryPos(1),SecondaryPos(4)-SecondaryPos(2)] + 1;
PrimaryLowerLeft   = [PrimaryPos(1)  ,
((SecondarySize(2) - PrimaryPos(2))   -
PrimarySize(2)) + 2];
SecondaryLowerLeft = [SecondaryPos(1),
((PrimarySize(2)   - SecondaryPos(2)) -
PrimarySize(2)) + 2];

% Display a dialog to allow the user to select the
% stimulus display that they wish to use.
MonitorToUse = uigetpref('Monitors','One',...
         'Stimulus Monitor Selection Dialog',...
         'Select which monitor to use.',{'1','2'},...
         'CheckboxString','Always use this monitor.');
switch MonitorToUse;
case '1'
    SelectedPos = [PrimaryLowerLeft,  PrimarySize  ];
case '2'
    SelectedPos = [SecondaryLowerLeft,SecondarySize];
end
```

```
% Pick an image file to display, and get the full path
% to the file.
% (The image file must be on your MATLAB path).
ImageFile = which('Glasgow.bmp');

% Read the selected image file, getting both the image
% and the palette data.
[Image,Palette] = imread(ImageFile);

% Create a figure window in which to display the
% stimulus, then stimulus on the figure window,
% Load the bitmap image onto the selected monitor,
% scaling appropriately.
Figure1Handle = figure(1); AxesHandle = axes;
set(AxesHandle,  'Position', [0 0 1 1]);
set(Figure1Handle, 'MenuBar',
'none','ToolBar','none','Position',SelectedPos);

imagesc(Image);
colormap(Palette);
axis('off');

% Create Mimic Screen and load Bitmap image

vetCreateMimicScreen;
vetSetMimicScreenDimensions(400, 0, 400, 300);
vetSetFixationPeriod(300);
vetSetFixationRange(10);
vetSetMimicPersistenceType(CRS.ptMotionAndFixations);
vetLoadBmpFileToMimicScreen(ImageFile,1);

% Start tracking.
vetClearDataBuffer;
vetStartTracking;

% Track for 30 seconds, then stop tracking
pause(30);
vetStopTracking;

% Tidy up by clearing away the camera and mimic
% screens.
vetDestroyCameraScreen;
vetDestroyMimicScreen;
close(figure1Handle);

% Retrieve the recorded eye positions
% without removing them from the buffer.
Remove = false;
DATA = vetGetBufferedEyePositions(Remove);
```

```
% Display the retrieved positions
figure(2); cla; hold on;
plot(DATA.fickPositions(:,1),'b'); %Longitude in blue
hold on;
plot(DATA.fickPositions(:,2),'r'); %Latitude in red
grid on;

% Save the results to disk as a comma delimited file.
CurrentDirectory = cd;
tempfile = [CurrentDirectory,'\myResults.csv'];
vetSaveResults(tempfile, CRS.ffCommaDelimitedNumeric);

% Clear the data buffer.
vetClearDataBuffer;
```

Example 2: Triggered Saccade Stimulus for ViSaGe

Example 2 is specifically designed to demonstrate how the High-Speed system can be integrated with a Cambridge Research Systems ViSaGe for a typical oculomotor research application. This example calibrates a test subject, generates a series of fixation and saccade targets and tracks the subject's eye positions. The eye movement results and stimulus timing triggers are then displayed as a graph and saved to a file.

The first section of code initialises the ViSaGe, selects the video source, creates Camera and Mimic windows and performs calibration as in the previous MATLAB example.

```
function demoVETsacc1
% A simple VET demo to elicit reflexive horizontal
% saccades. This demo requires a ViSaGe
% ------------------------------------------------
global CRS;
crsLoadConstants;
Check we are running on a VSG ViSaGe
CheckCard = crsGetSystemAttribute(CRS.DEVICECLASS);
if(CheckCard ~= 7)
   error('Sorry, this demonstration requires a VSG
ViSaGe.'); end;

% Select the VET camera to use.
vetSetStimulusDevice(CRS.deVSG);
errorCode = vetSelectVideoSource(CRS.vsUserSelect);
if(errorCode<0); error('Video Source not selected.');
end;
```

```
% Calibrate the video eyetracker
vetCreateCameraScreen;
errorCode = vetCalibrate;
if(errorCode<0); error('Calibration not completed.');
end;

% Create the Mimic Screen window
vetCreateMimicScreen;
vetSetMimicScreenDimensions(400, 0, 400, 300);
vetSetFixationPeriod(300);
vetSetFixationRange(10);
vetSetMimicPersistenceType(CRS.ptMotionAndFixations);
```

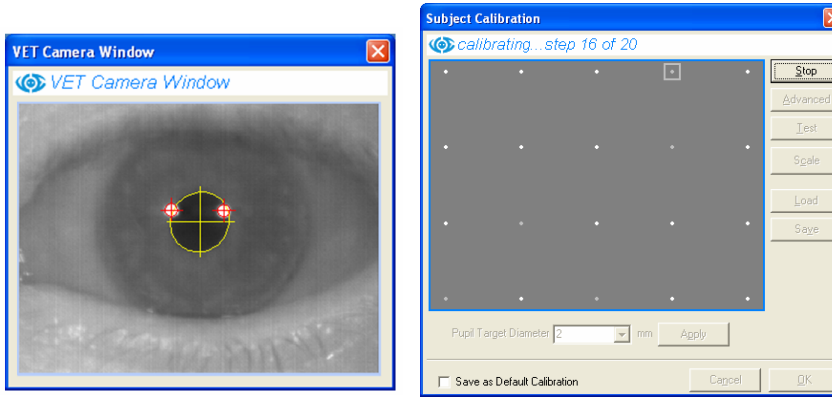


Fig 60. 250 Hz Live Camera and Calibration Windows (Calibration in Progress)

The next section of code defines the colours, size and shape of all stimuli and draws the stimuli into video memory. In this example we have chosen a green circle as the fixation target and red circles as saccade targets. All circles have a viewed diameter of 0.3 degrees.

```
% Set the palette and pen levels for drawing red and
% green dots on a mean grey background.
GreyLevel  = 1; GreyRGB  = [0.5, 0.5, 0.5];
crsPaletteSetPixelLevel(GreyLevel,  GreyRGB );
RedLevel   = 2; RedRGB   = [1.0, 0.0, 0.0];
crsPaletteSetPixelLevel(RedLevel,   RedRGB  );
GreenLevel = 3; GreenRGB = [0.0, 1.0, 0.0];
crsPaletteSetPixelLevel(GreenLevel, GreenRGB);
```

```
% Draw the fixation point and target on their
% respective video pages, whilst displaying a blank
% page to 'hide' the drawing
TargetSize = crsDegreesToPixels([0.3,0.3]);
BlankPage    = 1;
crsClearPage( BlankPage,   GreyLevel );
FixationPage = 2;
crsClearPage( FixationPage,GreyLevel );
TargetPage   = 3;
crsClearPage( TargetPage,  GreyLevel );
crsSetDisplayPage(BlankPage);

% Draw a green fixation point on the fixation page
crsSetDrawPage(FixationPage);
crsSetPen1(GreenLevel);
crsDrawOval([0,0],TargetSize);

% Draw a red target on the target page
crsSetDrawPage(TargetPage);
crsSetPen1(RedLevel);
crsDrawOval([0,0],TargetSize);
```

The next section of code defines the randomised timings and locations of the fixation and saccade target stimuli. This is designed to prevent the test subject from anticipating the position or timing of the next stimulus. This test will present a total of 10 horizontal fixation and saccade targets with displacements of 0 (fixation) 5, 7.5 and 10 degrees.

```
% Specify the timing for one trial.
% We use a 1 - 3 second random interval to elicit
% reflexive, rather than predictive saccades.
PageOrder  = [FixationPage,TargetPage,FixationPage];
MinTime    = crsSecondsToFrames([  0.5,  1,  0.5]);
MaxTime    = crsSecondsToFrames([  1.5,  3,  1.5]);

% Replicate the trials to provide data for all trials
NumTrials  = 10;
Pages      = repmat(PageOrder,1,NumTrials);
MinTime    = repmat(MinTime,  1,NumTrials);
MaxTime    = repmat(MaxTime,  1,NumTrials);
Times      = round(MinTime + (rand .* (MaxTime-
MinTime)));

% Specify target locations from 5 to 10 degrees (We
% invert the x and y locations because we are moving
% the video window offset, not the video memory).
Xlocations = -crsDegreesToPixels([ 5.0, 7.5, 10.0]);
Ylocations = -crsDegreesToPixels([ 0.0, 0.0, 0.0]);
```

```
 % Generate random locations for each entry.
Indices    = ceil(rand(size(Pages)) .*
numel(Xlocations));
Xlocations = Xlocations(Indices);
Ylocations = Ylocations(Indices);

% Make sure the fixation point always appears at 0,0
Xlocations(Pages==FixationPage) = 0;
Ylocations(Pages==FixationPage) = 0;
```

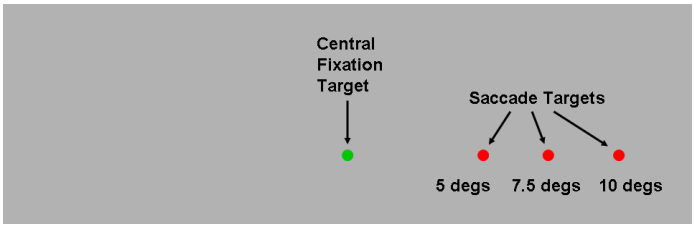


Fig 61. Fixation and Saccade Targets

The next section of code defines triggers and associates them with the relevant video pages. We then commence eye tracking and present the stimuli. The Camera and Mimic screens are destroyed when the test is complete.

```
% Specify triggers to identify when a target shift has
% occurred.
% (The VET captures digital output lines 6, 7 and 8).
Triggers = zeros(size(Pages));
Triggers(Pages~=FixationPage) = bin2dec('011100000');

% Set up RTS page cycling.
Repeating = false;
crsSimplePageCycle(Pages,Xlocations,Ylocations,Times,T
riggers,Repeating);

% Start eye tracking and stimulus cycling.
vetStartTracking;
crsSetCommand(CRS.CYCLEPAGEENABLE);
pause(crsFramesToSeconds(sum(Times(:))));
crsSetDisplayPage(BlankPage);
 vetStopTracking;

% Tidy up by clearing away the camera screen.
vetDestroyCameraScreen;
vetDestroyMimicScreen;
```

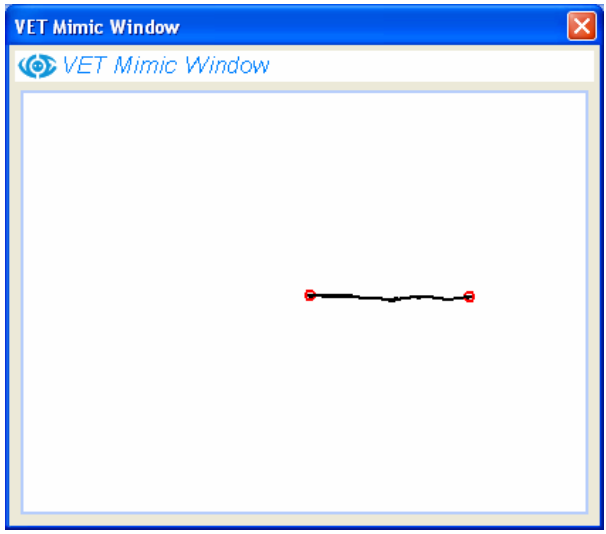


Fig 62. Mimic Window during Saccade Test

Finally, the tracked eye positions and triggering results are plotted and the data is saved to MATLAB file:

```
% Retrieve the recorded eye positions
remove = false;
DATA = vetGetBufferedEyePositions(remove);

% Display the eye positions and triggers
g = figure;
plot(DATA.ficksPositions(:,1),'b'); % longitude in blue
hold on;
plot(DATA.ficksPositions(:,2),'r'); % latitude in red
hold on;
plot(DATA.digitalIO,'g'); % triggers in green
grid on;

% Finally, save the results to disk as a .mat file.
tempfile = 'C:\myResults.mat';
vetSaveResults(tempfile, CRS.ffMATfile);
```

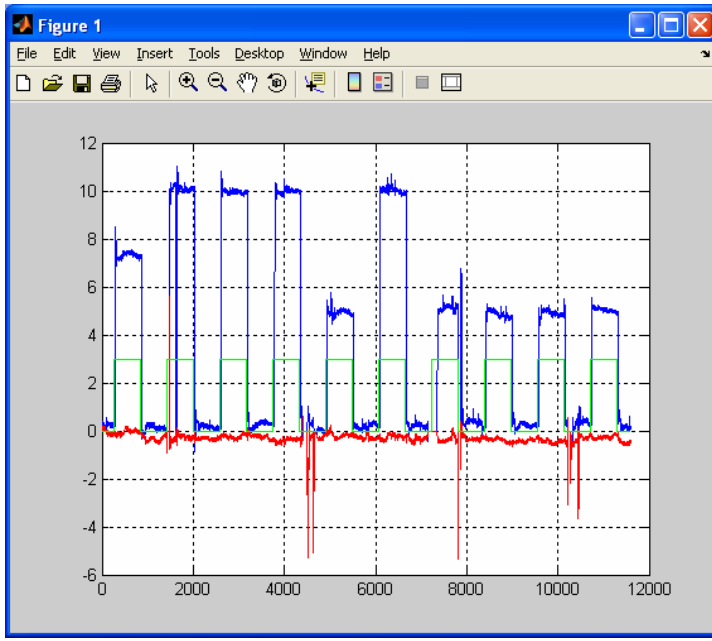


Fig 63. Tracked Eye Data for Triggered Saccade Stimulus

The blue and red traces in Fig 63 represent horizontal and vertical angular eye movements, while the green trace represents the triggers output by the ViSaGe to coincide with the presentations of saccade targets. Furthermore, opening the **myResults.mat** file in MATLAB's current directory, will declare all your results as variables in MATLAB's own workspace as shown in Fig 64

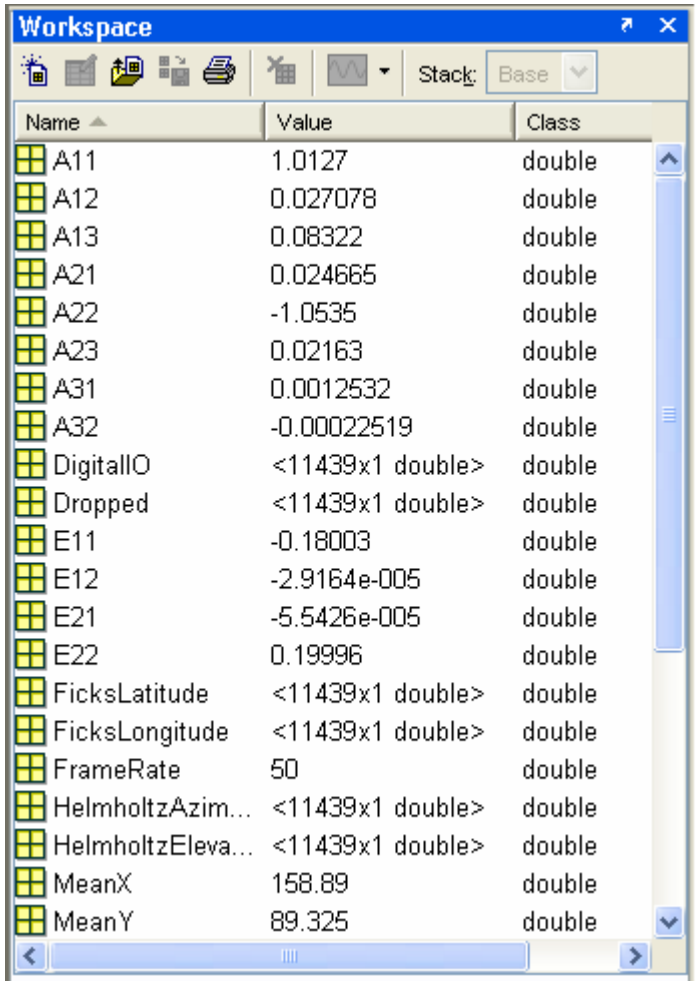


Fig 64. Calibration and Tracked Eye Data as MATLAB Variables

You can now use MATLAB to analyze, plot or process any of your calibration or recorded eye results data.

The full code listing for demoVETsacc1 is as follows:

```
function demoVETsacc1
% A simple VET demo to elicit reflexive horizontal
% saccades.
% This demo requires a CRS ViSaGe
% ------------------------------------------------
global CRS;
crsLoadConstants;

Check we are running on a VSG ViSaGe
CheckCard = crsGetSystemAttribute(CRS.DEVICECLASS);
if(CheckCard ~= 7)
   error('Sorry, this demonstration requires a VSG
ViSaGe.');
end;

% Select the VET camera to use.
vetSetStimulusDevice(CRS.deVSG);
errorCode = vetSelectVideoSource(CRS.vsUserSelect);
if(errorCode<0); error('Video Source not selected.');
end;

% Calibrate the video eyetracker
vetCreateCameraScreen;
errorCode = vetCalibrate;
if(errorCode<0); error('Calibration not completed.');
end;

% Create the Mimic Screen window
vetCreateMimicScreen;
vetSetMimicScreenDimensions(400, 0, 400, 300);
vetSetFixationPeriod(300);
vetSetFixationRange(10);
vetSetMimicPersistenceType(CRS.ptMotionAndFixations);

% Set the palette and pen levels for drawing red and
% green dots on a mean grey background.
GreyLevel  = 1; GreyRGB  = [0.5, 0.5, 0.5];
crsPaletteSetPixelLevel(GreyLevel,  GreyRGB );
RedLevel   = 2; RedRGB   = [1.0, 0.0, 0.0];
crsPaletteSetPixelLevel(RedLevel,   RedRGB  );
GreenLevel = 3; GreenRGB = [0.0, 1.0, 0.0];
crsPaletteSetPixelLevel(GreenLevel, GreenRGB);

% Draw the fixation point and target on their
% respective video pages, whilst displaying a blank
% page to 'hide' the drawing
TargetSize = crsDegreesToPixels([0.3,0.3]);
BlankPage    = 1;
crsClearPage( BlankPage,   GreyLevel );
FixationPage = 2;
crsClearPage( FixationPage,GreyLevel );
```

```
TargetPage   = 3;
crsClearPage( TargetPage,  GreyLevel );
crsSetDisplayPage(BlankPage);

% Draw a green fixation point on the fixation page
crsSetDrawPage(FixationPage);
crsSetPen1(GreenLevel);
crsDrawOval([0,0],TargetSize);

% Draw a red target on the target page
crsSetDrawPage(TargetPage);
crsSetPen1(RedLevel);
crsDrawOval([0,0],TargetSize);

% Specify the timing for one trial.
% We use a 1 - 3 second random interval to elicit
% reflexive, rather than predictive saccades.
PageOrder  = [FixationPage,TargetPage,FixationPage];
MinTime    = crsSecondsToFrames([  0.5,  1,  0.5]);
MaxTime    = crsSecondsToFrames([  1.5,  3,  1.5]);

% Replicate the trials to provide data for all trials
NumTrials  = 10;
Pages      = repmat(PageOrder,1,NumTrials);
MinTime    = repmat(MinTime,  1,NumTrials);
MaxTime    = repmat(MaxTime,  1,NumTrials);
Times      = round(MinTime + (rand .* (MaxTime-
MinTime)));

% Specify target locations from 5 to 10 degrees.(We
% invert the x and y locations because we are moving
% the video window offset, not the video memory).
Xlocations = -crsDegreesToPixels([ 5.0, 7.5, 10.0]);
Ylocations = -crsDegreesToPixels([ 0.0, 0.0, 0.0]);

% Generate random locations for each entry.
Indices    = ceil(rand(size(Pages)) .*
numel(Xlocations));
Xlocations = Xlocations(Indices);
Ylocations = Ylocations(Indices);

% Make sure the fixation point always appears at 0,0
Xlocations(Pages==FixationPage) = 0;
Ylocations(Pages==FixationPage) = 0;

% Specify triggers to identify when a target shift has
% occurred.
% (The VET captures digital output lines 6, 7 and 8).
Triggers = zeros(size(Pages));
Triggers(Pages~=FixationPage) = bin2dec('011100000');
```

```
% Set up RTS page cycling.
Repeating = false;
crsSimplePageCycle(Pages,Xlocations,Ylocations,Times,T
riggers,Repeating);

% Start eyetracking and stimulus cycling.
vetStartTracking;
crsSetCommand(CRS.CYCLEPAGEENABLE);
pause(crsFramesToSeconds(sum(Times(:))));
crsSetDisplayPage(BlankPage);

vetStopTracking;

% Tidy up by clearing away the camera screen.
vetDestroyCameraScreen;
vetDestroyMimicScreen;

% Retrieve the recorded eye positions
remove = false;
DATA = vetGetBufferedEyePositions(remove);

% Display the eye positions and triggers
g = figure;
plot(DATA.ficksPositions(:,1),'b'); % longitude in blue
hold on;
plot(DATA.ficksPositions(:,2),'r'); % latitude in red
hold on;
plot(DATA.digitalIO,'g'); % triggers in green
grid on;

% Finally, save the results to disk as a .mat file.
tempfile = 'C:\myResults.mat';
vetSaveResults(tempfile, CRS.ffMATfile);
```

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Appendix A
MATLAB Commands

The Video Eyetracker Toolbox can be controlled using MATLAB or any Windows programming tool that supports Microsoft COM.

The CRS Toolbox for MATLAB contains the commands you need to use to control the Video Eyetracker Toolbox. To download the CRS Toolbox for MATLAB, login to the CRS Support Portal (www.crsltd.com/support/login).

What follows is a listing of the functions that make up the MATLAB interface and the ways in which they can be used. A description of the COM programming interface and additional demonstrations are available from the Cambridge Research Systems support portal (www.crsltd.com/support/login).

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vetAddRegion

Video Eyetracker Toolbox Regions-Of-Interest are intended to assist with fixation monitoring tasks. These regions are defined as rectangular patches lying in the plane of the stimulus display. There may be as many regions as you wish, but no two regions may overlap. Each region has a unique identifying number, called the **regionHandle**. If the subject's direction of gaze intersects a region, that region's identifying number is recorded in the Video Eyetracker Toolbox data buffer along with all the other eye position data that is being collected. The currently active region's **RegionHandle** can also be obtained using the **vetGetActiveRegion** function. When the direction of gaze first enters a region, the MATLAB function specified using **vetSetCallbackRegionChanged** is executed.

MATLAB Syntax

```
[regionHandle] =
vetAddRegion(leftMM,topMM,rightMM,bottomMM);
```

Parameters

LeftMM – A rational scalar (1-by-1 matrix), specifying the left edge of the region of interest.

TopMM – A rational scalar (1-by-1 matrix), specifying the top edge of the region of interest.

RightMM – A rational scalar (1-by-1 matrix), specifying the right edge of the region of interest.

BottomMM – A rational scalar (1-by-1 matrix), specifying the bottom edge of the region of interest.

Return Values

regionHandle - An integer scalar (1-by-1 matrix), denoting the region created by the operation.

Example

[regionHandle] = **vetAddRegion**(50, 50, 100, 100);

will add a square Region of Interest 50mm in size with a mid point 75mm right and 75mm up from the centre of the screen.

See also

vetDeleteRegion, vetClearAllRegions, vetRegionCount, vetSetCallbackRegionChanged

vetCalibrate

This function launches a calibration dialog that can be used to configure and control subject calibration. Through this dialog, eye position and pupil diameter can be calibrated, and calibration options can be configured. Normally, calibration options are recalled from the previous session; If specific calibration options are required, they can be specified using the **vetCalibrateAdvanced** function.

The **vetCalibrate** function will display targets on either a Secondary Windows VGA display, or on a VSG, depending on the stimulus device that has been selected using the **vetSetStimulusDevice** function.

If a 'user' stimulus device has been selected, then it is up to the user to draw fixation targets on their stimulus device, under the control of user- specifiable callbacks. You can specify these callbacks using the following functions: **vetSetCallbackInitialiseDisplay**, **vetSetCallbackClearDisplay**, **vetSetCallbackDrawTarget**. User device parameters also need to be set using the **vetSetDeviceParameters** function.

NOTE: You must select the video source and the stimulus device before calling **vetCalibrate**. See demoVETQuickstart for a worked example.

MATLAB Syntax

```
vetCalibrate;
```

See also

vetCalibrateAdvanced, vetCalibrationStatus,vetSelectVideoSource, vetStartTracking, vetLoadCalibrationFile, vetSaveCalibrationFile

vetCalibrateAdvanced

Like **vetCalibrate** this function can be used to calibrate a subject. **vetCalibrateAdvanced** opens the Calibration window but unlike **vetCalibrate** it passes a number of parameters to the window overwriting the Calibration window's default settings. Thus, this function makes it possible to perform a non-standard calibration without using the Advanced Calibration Parameter dialog. This function returns True (1) if the calibration has been successful, otherwise will return False (0). If you wish to calibrate a subject without passing any parameters you should use the Video Eyetracker Toolbox **vetCalibrate** function instead.

MATLAB Syntax

```
calibrationSuccessful =
vetCalibrateAdvanced(xPoints,yPoints,targetShape,
targetSize,targetColour,backgroundColour, ...
scaleFactor,fixationDuration,accuracyLevel, ...
imageFilename);
```

Parameters

numX – A scalar integer value in the closed interval [2,10] indicating the number of dots across to use.

numY – A scalar integer value in the closed interval [2,10] indicating the number of dots down to use.

targetShape – A scalar integer value drawn from the following set:

CRS.tsSquare

CRS.tsCircle

CRS.tsCross

CRS.tsImage

targetSize – A rational scalar value in the closed interval [0.01, 5.0]. This indicates the diameter of the target, measured in degrees of Arc. This value is ignored when a tsImage is selected.

targetColour – A 3-by-1 or 1-by-3 RGB colour vector, each component value a rational number in the interval [0, 1].

backgroundColour – A 3-by-1 or 1-by-3 RGB colour vector, each component value a rational number in the interval [0, 1].

scaleFactor – A scalar value in the interval [1,100], indicating the calibration area as a percentage of total screen area, a sensible value for this parameter would be 90%.

fixationDuration – A scalar value, measured in milliseconds, indicating how long a fixation needs to last in order to be detected. - A sensible value for this parameter would be around 500ms.

accuracyLevel – A scalar integer value drawn from the following set:

CRS.acLow

CRS.acMedium

CRS.acHigh

This value indicates how much movement will be tolerated when detecting a fixation.

imageFilename – A char array. (Matlab string) containing the filename and full path. This parameter should be set to an empty string if targetShape has been set to anything other than tsImage.

Example

```
vetCalibrateAdvanced(3,3,CRS.tsSquare,0.5,[1;0;0],[0;0;1],90,100,
CRS.acMedium,'');
```

See also

vetCalibrate, vetCalibrationStatus, vetSelectVideoSource, vetStartTracking, vetLoadCalibrationFile, vetSaveCalibrationFile

vetClearAllRegions

This function deletes all Regions-Of-Interest from the Video Eyetracker Toolbox Regions-of-interest list. See the help for **vetAddRegion** for a description of Regions-Of-Interest.

MATLAB Syntax

```
vetClearAllRegions;
```

See also

vetAddRegion, vetDeleteRegion, vetRegionCount

vetClearDataBuffer

The Video Eyetracker Toolbox maintains a buffer in which it records eye position and related eyetracking data. If you are running multiple trials back to back, and your experimental paradigm requires you to collect data separately for each trial, this function will allow you to clear the buffer between trials.

MATLAB Syntax

```
vetClearDataBuffer;
```

See also

vetGetLatestEyePosition, vetStartTracking

vetClearMimicScreenBitmap

Use this function to clear the background bitmap displayed on the mimic screen.

MATLAB Syntax

```
vetClearMimicScreenBitmap;
```

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetMimicPersistence, vetMimicPersistenceType, vetMimicTraceColor

vetCreateCameraScreen

This function creates a camera screen, displaying live video from the eye tracking cameras, providing visual feedback of pupil and Purkinje reflection tracking. You should call this function just prior to calibration so that you can adjust the position and focus of the camera to obtain a high quality image of your subject's eye for tracking.

MATLAB Syntax

```
vetCreateCameraScreen;
```

See also

vetSelectVideoSource, vetDestroyCameraScreen, vetSetCameraScreenDimensions

vetCreateMimicScreen

This function creates the mimic screen window using the default system parameters. The mimic screen is used to give visual feedback on where the subject is looking.

MATLAB Syntax

```
vetCreateMimicScreen;
```

See also

vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetMimicPersistence, vetMimicPersistenceType, vetLoadBitmapToMimicScreen, vetMimicTraceColor

vetDeleteRegion

This function is used to delete a specific region from the Video Eyetracker Toolbox Regions-Of-Interest list. NOTE: It is often preferable to delete all regions at once using the **vetClearAllRegions** function.

MATLAB Syntax

```
vetDeleteRegion(RegionIndex);
```

See also

vetAddRegion, vetClearAllRegions, vetRegionCount

vetDestroyCameraScreen

This function destroys the camera screen control created using the **vetCreateCameraScreen** function

MATLAB Syntax

```
vetDestroyCameraScreen;
```

See also

vetCreateCameraScreen, vetSetCameraScreenDimensions

vetDestroyMimicScreen

This function destroys the mimic screen. A mimic screen can be created using the **vetCreateMimicScreen** function. Only one mimic screen can exist at any one time. Mimic screens are used to display the recent gaze direction in a graphical format.

MATLAB Syntax

```
vetDestroyMimicScreen;
```

See also

vetCreateMimicScreen, vetSetMimicScreenDimensions, vetMimicPersistence, vetMimicPersistenceType, vetLoadBitmapToMimicScreen, vetMimicTraceColor

vetGetActiveRegion

This function returns the current active Video Eyetracker Toolbox Region-Of -Interest. This is the region that the subject's direction of gaze currently intersects. If the subject's direction of gaze does not currently intersect a specified Region-Of-Interest, this function will return a negative number (-1).

Regions-of-interest can be specified using the **vetAddRegion** function, and are intended to assist with fixation-monitoring tasks. The current region is also returned by **vetGetLatestEyePosition** and **vetGetBufferedEyePositions**. When the subject's direction

of gaze enters a region, the MATLAB command specified with the **vetSetCallbackRegionChanged** function is executed.

MATLAB Syntax

```
activeRegion = vetGetActiveRegion;
```

Return Values

activeRegion – An integer.scalar (1-by-1 matrix) in the interval [1,int_max], showing the current active region.

See also

vetAddRegion, vetGetLatestEyePosition

vetGetBufferedEyePositions

This function returns eye position data from the buffer that is created and maintained by the Video Eyetracker Toolbox software. Eye positions that are returned by this function are (by default) removed from the data buffer, so subsequent calls will not return duplicate data.

If there are no points available in the buffer, a structure filled with zeros is returned, together with a non-zero (-1) ErrorCode. NOTE: In order to determine if the subject is fixating, eye position data is delayed by the user-specifiable fixation period, defined using the **vetSetFixationPeriod** function.

This function has two optional parameters, a Boolean/logical value: **removeFromBuffer**, and a numeric (integer) value: **maximumPoints**. If the **removeFromBuffer** parameter is set to False, then data points are left in the VET buffer, allowing them to be retrieved again by a second call. If the **removeFromBuffer** parameter is set to True, then data points are deleted from the buffer after they are read. The **maximumPoints** parameter allows you to limit the number of points returned by this function. This is useful if the buffer is large and you can only deal with a limited number of points at any one time.

MATLAB Syntax

```
data = vetGetBufferedEyePositions
```

```
data = vetGetBufferedEyePositions(removeFromBuffer)
data = vetGetBufferedEyePositions(maximumPoints)
data = vetGetBufferedEyePositions(maximumPoints,
removeFromBuffer);
```

Parameters

maximumPoints – (Optional parameter) A scalar integer indicating the maximum number of points to return to MATLAB.

removeFromBuffer – (Optional parameter) A scalar logical controlling the removal of returned eye positions from the VET buffer.

Return Values

data – A MATLAB structure containing the VET eye position data:

Data.timeStamps – Time in milliseconds since tracking started.

Data.tracked – A Boolean value where 0 = FALSE and 1 = TRUE

Data.calibrated – A Boolean value where 0 = FALSE and 1 = TRUE

Data.pupilDiameter – Pupil diameter in millimetres.

Data.mmPositions – Direction of gaze projected onto stimulus display, in mm: [X,Y]

Data.ficksPositions – Eye rotation in Fick coordinates [Longitude, Latitude]

Data.helmholtzPositions – Eye rotation in Helmholtz coordinates [Elevation, Azimuth].

Data.region – Current region number

Data.fixation – A Boolean value where 0 = FALSE and 1 = TRUE

Data.digitalIO – A value containing the combined digital IO values (see page 53 for details)

Data.dropped – A Boolean value where 0 = FALSE and 1 = TRUE

Data.trigIn – (High-Speed system only) EIB Trigger input values.

See also

vetIsEyeDataAvailable, vetGetLatestEyePosition, vetClearDataBuffer

vetGetCalibrated

This function returns True if the subject has been calibrated and False otherwise. You can use the **vetCalibrate** or **vetCalibrateAdvanced** functions to calibrate your subject's direction of gaze.

MATLAB Syntax

```
[isCalibrated] = vetGetCalibrated;
```

Return Values

isCalibrated – A Boolean (1 x 1 matrix) where 0 = FALSE and 1 = TRUE.

See also

vetGetPupilCalibrated

vetGetEIB_LEDsENABLED

This property will determine whether the Eyetracker Interface Box LEDs are currently set on or off. This property, when read, will return true or false accordingly.

MATLAB Syntax

```
LEDsEnabled = vetGetEIB_LEDsEnabled;
```

Return Values

LEDsEnabled – A Boolean (1-by-1 matrix) where 0 = FALSE and 1 = TRUE

See also

vetVideoSourceType, vetSetEIB_LEDsEnabled

vetGetEIB_XYOutputType

This function will return the XY output type for the Eyetracker Interface Box. (The values output on the two analog channels).

These can either be 100 mm per volt, 1000 mm per volt, degrees elevation + azimuth (Helmholtz), or degrees longitude + latitude (Fick).

This value will be one of the following constants:

CRS.otMM100 - MM, 100 mm / V

CRS.otMM1000 - MM, 1000 mm / V

CRS.otHelm1 - 0.1 Volts per degree Helmholtz coordinates

CRS.otFicks1 - 0.1 Volts per degree Fick coordinates

MATLAB Syntax

```
XYOutputType = vetGetEIB_XYOutputType;
```

Return Values

XYOutputType – An integer constant which will be one of the values listed above.

See also

vetGetLatestEyePosition, vetVideoSourceType, vetSetEIB_XYOutputType

vetGetFixationLocation

This function returns the location of the current fixation. This function will return [0, 0, 0] if the subject is not fixating.

MATLAB Syntax

```
[isFixating,xPositionMM,yPositionMM] =
vetGetFixationLocation;
```

Return Values

isFixating – A logical value (1-by-1 matrix) containing the value 0 if the subject is not fixating or 1 if the subject is fixating.

xPositionMM – The x position (in mm) of the fixation, or 0 if the subject is not fixating.

yPositionMM – The y position (in mm) of the fixation, or 0 if the subject is not fixating.

See also

vetGetLatestEyePosition

vetGetLatestEyePosition

This function returns the most recent eye position analysed by the Video EyeTracker Toolbox. This data point is NOT removed from the data buffer that the Video Eyetracker Toolbox maintains. (I.e. you can get the same results later using **vetGetBufferedEyePositions**).

If there are no points available in the buffer, a MATLAB structure filled with zeros is returned, together with a non-zero (-1) ErrorCode. This may happen if you attempt to read data soon after tracking starts, as eye position data can be delayed by the user-specifiable fixation period, defined using the **vetSetFixationPeriod** command.

MATLAB Syntax

```
Data = vetGetLatestEyePosition;
```

Return Values

Data – A MATLAB structure containing the VET eye position data.

Data.timeStamps – Time in milliseconds since tracking started.

Data.tracked – A Boolean value where 0 = FALSE and 1 = TRUE

Data.calibrated – A Boolean value where 0 = FALSE and 1 = TRUE

Data.pupilDiameter – Pupil diameter in millimetres.

Data.mmPositions – Direction of gaze projected onto stimulus display, in mm: [X,Y]

Data.ficksPositions – Eye rotation in Fick coordinates [Longitude, Latitude]

Data.helmholtzPositions – Eye rotation in Helmholtz coordinates [Elevation, Azimuth].

Data.region – Current region number

Data.fixation – A Boolean value where 0 = FALSE and 1 = TRUE

Data.digitalIO – A value containing the combined digital IO values (see page 53 for details)

Data.dropped – A Boolean value where 0 = FALSE and 1 = TRUE

Data.trigIn – (High-Speed system only) EIB Trigger input values.

See also

vetIsEyeDataAvailable, vetGetBufferedEyePosition

vetGetMimicScreenBitmap

This function returns the mimic window bitmap as a MATLAB matrix.

MATLAB Syntax

```
ImageMatrix = vetGetMimicScreenBitmap;
```

Return Values

ImageMatrix – A MATLAB matrix containing the mimic window bitmap.

See also

vetCreateMimicScreen, vetLoadBitmapToMimicScreen

vetGetPupilCalibrated

This function returns True if the pupil size has been calibrated; False otherwise. The **vetCalibrate** or **vetCalibrateAdvanced** functions can be used to calibrate your subject's pupil size.

MATLAB Syntax

```
[isPupilCalibrated] = vetGetPupilCalibrated;
```

Return Values

isPupilCalibrated – A Boolean (1 x 1 matrix) where 0 = FALSE and 1 = TRUE.

See also

vetGetCalibrated

vetGetRegionCount

The **vetGetRegionCount** function returns the number of Regions-Of-Interest that are currently defined in the Video Eyetracker Toolbox Regions-Of-Interest list.

MATLAB Syntax

```
RegionCount = vetGetRegionCount;
```

Return Values

regionCount – A non-negative (zero included) integer scalar (1-by-1 matrix).

See also

vetAddRegion, vetDeleteRegion, vetClearAllRegions

vetGetResultsCount

The Video Eyetracker Toolbox maintains a buffer of eye position data. The **vetGetResultsCount** function returns the number of results currently stored in this buffer.

MATLAB Syntax

```
resultsCount = vetGetResultsCount;
```

Return Values

resultsCount – A non-negative (zero included) integer scalar (1-by-1 matrix).

See also

vetClearDataBuffer, vetGetLatestEyePosition, vetIsEyeDataAvailable

vetGetTracking

This function will return True or False, depending on whether the Video Eyetracker Toolbox is currently tracking.

MATLAB Syntax

```
tracking = vetGetTracking;
```

Return Values

tracking – A boolean value (1-by-1 matrix), where 0 = FALSE and 1 = TRUE.

See also

vetStartTracking, vetStopTracking

vetGetToolboxVersion

This function returns the current video eyetracker toolbox version number.

MATLAB Syntax

```
toolboxVersion = vetGetToolboxVersion;
```

Return Values

toolboxVersion – The Video Eyetracker Toolbox Software version number.

vetGetVideoSourceFile

If the Video Eyetracker Toolbox is set to play and track a pre-recorded video file then calling **vetGetVideoSourceFile** will return the full name and file path of the .CAM file that has been selected.

MATLAB Syntax

```
videoSourceFile = vetGetVideoSourceFile;
```

Return Values

videoSourceFile – A char array (a Matlab string, between 1 and 500 characters long, inclusive of the terminating null character).

See also

vetSelectVideoSource

vetGetVideoSourceType

The Video Eyetracker Toolbox can obtain a video stream from a number of different camera types. The function **vetSelectVideoSource** allows you to specify the video source that you are using. This function returns the value that has been set using **vetSelectVideoSource**, or zero if no source has yet been selected.

MATLAB Syntax

```
videoSourceType = vetGetVideoSourceType;
```

Return Values

videoSourceType – An integer scalar value: one of the following constants:

CRS.vsCamera	Progressive scan 50 Hz camera (no identifying label on camera case)
CRS.vsFile	Takes video from a pre-recorded saved 'CAM' file
CRS.vsCameraI	Interlaced mode 50 Hz camera (white 'Camera-I' label on camera case)
CRS.vsHighSpeedCamera60	High-Speed Camera running at 60Hz
CRS.vsHighSpeedCamera100	High-Speed Camera running at 100Hz
CRS.vsHighSpeedCamera160	High-Speed Camera running at 160Hz
CRS.vsHighSpeedCamera200	High-Speed Camera running at 200Hz
CRS.vsHighSpeedCamera250	High-Speed Camera running at 250 Hz

See also

vetSelectVideoSource

vetIsEyeDataAvailable

This function returns the value TRUE (1) if there are any results in the data buffer. Results can only be entered into the buffer if the Toolbox has been successfully calibrated and tracking has been started.

MATLAB Syntax

```
eyeDataAvailability =  vetIsEyeDataAvailable;
```

Return Values

eyeDataAvailability – An integer scalar (1-by-1 matrix) holding the value 1 if eye data is available, and 0 if it is not.

See also

vetClearDataBuffer, vetLatestGetEyePosition

vetLoadBmpFileToMimicScreen

Use this function to load a background bitmap onto the mimic screen. The mimic screen is a graphical representation of eye location. If a scaled image of the stimulus (or of landmarks in the stimulus) is specified by the experimenter, then the mimic screen will display the subject's gaze with respect to landmarks in the stimulus image.

MATLAB Syntax

```
vetLoadBmpFileToMimicScreen(ImageMatrix,
ScaleToStimulusDevice);
```

Parameters

ImageMatrix – Specifies the image values to be loaded onto the mimic window. This should be either a 3-dimensional width-by-height-by-3

matrix (1 page each for Red,Green and Blue), or a 2-dimensional width-by-height matrix for a monochrome image. The sample values in this matrix should lie in the range [0,1].

scaleToStimulusDevice – If this is TRUE, (1) the bitmap is scaled to the same scale as the selected stimulus device; otherwise if it is FALSE, (0), it is stretched to fill the whole of the mimic screen.

See also

vetCreateMimicScreen, vetLoadBitmapToMimicScreen

vetLoadCalibrationFile

This function loads a **Subject Calibration File**, previously created by the Toolbox. Subject Calibration files are identified by a .scf file extension and must be referenced by their absolute address. **vetLoadCalibrationFile** will return TRUE (1) if it is successful; FALSE (0) if it is unable to open the file.

MATLAB Syntax

```
vetLoadCalibrationFile(filename);
```

Parameters

Filename – A char array (matlab string) specifying the name of the calibration file to be opened. (You need to include the full windows path to the file).

Examples

vetLoadCalibrationFile ('C:\Temp\SubjectA.scf'); will open the file SubjectA.scf located in the temp folder stored on the C drive.

vetLoadCalibrationFile ('SubjectA.scf'); will fail to open because the full path to the file has not been specified.

See also

vetCalibrate, vetCalibrateAdvanced, vetSaveCalibrationFile

vetLoadBitmapToMimicScreen

Use this function to load a background bitmap onto the mimic screen. The mimic screen is a graphical representation of eye location. If a scaled image of the stimulus (or of landmarks in the stimulus) is specified by the experimenter, then the mimic screen will display the subject's gaze with respect to landmarks in the stimulus image.

MATLAB Syntax

```
vetLoadBitMapToMimicScreen(ImageMatrix;
ScaleToStimulusDevice);
```

Parameters

ImageMatrix – Specifies the image values to be loaded onto the mimic window. This should be either a 3-dimensional width-by-height-by-3 matrix, (1 page each for Red, Green and Blue), or a 2-dimensional width-by-height matrix for a monochrome image. The sample values in this matrix should lie in the range [0,1].

ScaleToStimusDevice – If this is TRUE (1), the bitmap is scaled to the same scale as the selected stimulus device; otherwise if it is FALSE (0) it is stretched to fill the whole of the mimic screen.

Note: Using the vetSetDeviceParameters function to set the presentation device to CRS.deUser results in the picture always being stretched to fill the entire mimic screen.

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetMimicPersistence, vetMimicPersistenceType, vetMimicTraceColor, vetSetDeviceParameters

vetSaveCalibrationFile

This function stores a subject's calibration data to a file, specified by Filename for future use. For example, this file could be used to provide a default calibration to be used with subjects that cannot fixate or are unable to calibrate for other reasons.

MATLAB Syntax

```
vetSaveCalibrationFile(filename);
```

Parameters

Filename – This specifies the name of the file which the calibration data will be saved to. NB: Windows standard separation characters (single backslashes) should be used. E.g.: C:\myDirectory\myCalibFile.scf

See also

vetCalibrate, vetCalibrateAdvanced, vetLoadCalibrationFile

vetSaveMimicScreenBitmap

Use this function to save a background bitmap copy of the mimic screen to a Windows bitmap image file.

MATLAB Syntax

```
vetSaveMimicScreenBitmap(Filename);
```

Parameters

Filename – This specifies the name of the file which the mimic window bitmap will be saved to. This parameter should be a MATLAB char array (string), including the full path to the image file.

See also

vetCreateMimicScreen, vetGetMimicScreenBitmap, vetLoadBitmapToMimicScreen

vetSaveResults

The Video Eyetracker Toolbox maintains a data buffer in which it records eye position data. The **vetSaveResults** function saves the contents of the data buffer to a user-specified file. Several different file formats are supported; although it is recommended that users use either the default **CRS.ffCommaDelimitedNumeric** format or **CRS.ffMATfile** format. The function **utilVETreadDataFile** is provided to read Comma Separated Value (CSV) files back into the MATLAB workspace.

MATLAB Syntax

```
vetSaveResults(filename);
vetSaveResults(filename, format);
```

Parameters

Filename – This specifies the name of the file which the results data will be saved to. This string must include the full path eg: C:\myDirectory\results.csv

Format – Use this flag to specify the format that the file will be written in. Accepted values include:

CRS.ffCommaDelimitedNumeric

CRS.ffSemiColonDelimitedNumeric

CRS.ffMATfile

If this parameter is omitted, CRS.ffCommaDelimitedNumeric is used by default.

See also

vetClearDataBuffer, vetGetLatestEyePosition, vetIsEyeDataAvailable,

vetSelectVideoSource

vetSelectVideoSource can be used to select the video source used by the Video Eyetracker Toolbox. **vetSelectVideoSource** can display a dialog box were the user can select the video source at run time, or alternatively it can directly specify the camera type or pre-recorded CAM file name.

MATLAB Syntax

```
vetSelectVideoSource(source, filename);
```

Parameters

Source – An integer scalar (1-by-1 matrix) holding one of the following values:

CRS.vsUserSelect	Displays a dialog box to allow the user to select a camera type

CRS.vsCamera	Progressive scan 50 Hz camera (no identifying label on camera case)
CRS.vsFile	Takes video from a pre-recorded saved 'CAM' file
CRS.vsCameraI	Interlaced mode 50 Hz camera (white 'Camera-I' label on camera case)
CRS.vsHighSpeedCamera60	High-Speed Camera running at 60Hz
CRS.vsHighSpeedCamera100	High-Speed Camera running at 100Hz
CRS.vsHighSpeedCamera160	High-Speed Camera running at 160Hz
CRS.vsHighSpeedCamera200	High-Speed Camera running at 200Hz
CRS.vsHighSpeedCamera250	High-Speed Camera running at 250 Hz

If the value of this parameter is set to CRS.vsUserSelect, then a dialog box will appear, prompting the user to select a video source. This is useful if you want to distribute your software.

If CRS.vsFile is used, then a filename is expected, specifying a prerecorded 'CAM' video file. CAM files can be created using the vetStartRecordingToFile and vetStopRecording functions. Other constant values refer to different camera types.

The High-Speed Video Eyetracker Toolbox camera can run at a selection of different speeds up to 250 Hz. Selecting the appropriate constant here will set the camera to run at the desired speed. NOTE: Higher speeds can put greater demands on your PC. The original Video Eyetracker Toolbox (50 Hz fixation monitor) has two camera types: CRS.vsCamera refers to the progressive scan-camera type, and CRS.vsCameraI refers to the newer mode Camera. Interlaced mode Cameras can be identified by a white or yellow 'Camera-I' sticker on the casing.

Filename – If the selected video source is CRS.vsFile, then this parameter should contain a full path to a prerecorded CAM file: e.g.: 'C:\myDirectory\myVideo.cam'

If the selected video source is CRS.vsUserSelect, then this parameter should contain a CAM file to default to.

If the selected video source is a camera of some description, then this parameter should be an empty string: ''.

See also

vetStartRecordingToFile, vetStopRecording, vetSetStimulusDevice, vetVideoSourceFile

vetSetCameraScreenDimensions

This function is used to set the dimensions of the camera screen control. Note that the camera screen control does not have to exist before this function is called.

MATLAB Syntax

```
vetSetCameraScreenDimensions(Left; Top; Width;
Height);
```

Parameters

Left – Specifies the left edge of the camera screen

Top – Specifies the top edge of the camera screen

Width – Specifies the width of the Camera screen

Height – Specifies the height of the Camera screen

Example

SetCameraScreenDimensions(10, 20, 400, 300) ;

will set the dimensions of the camera screen on its parent window so that it is located 10 pixels from the left, 20 pixels from the top, is 400 pixels wide and 300 pixels high.

See also

vetCreateCameraScreen, vetDestroyCameraScreen

vetSetDeviceParameters

If you are using a custom stimulus device such as an LED array or laser galvanometer system, then you should use this function to provide the Video Eyetracker Toolbox with information about your stimulus device, such as viewing distance and screen size.

This information is used during the VET calibration procedure to specify target locations for your calibration routine.

If you are using a Cambridge Research Systems VSG2/5, ViSaGe or a secondary Windows VGA display, you should use **vetSetStimulusDevice** instead of **vetSetDeviceParameters**, as viewing distance and stimulus display size are obtained automatically from the VSG Software Library or VGA Calibration utility.

MATLAB Syntax

```
vetSetDeviceParameters(device, ViewingDistance_mm,
Width_mm, Height_mm);
```

Parameters

Device – Only use the following value:

CRS.deUser;

Note: Setting device to deUser has a direct effect on the function vetLoadBitmapToMimicwindow

ViewingDistance_mm – Specifies the viewing distance of the subject to the stimulus display screen in millimetres.

Width_mm –this parameter specifies the width of the display screen in millimetres. If Device is not set to deUser this parameter is ignored.

Height_mm – this parameter specifies the Height of the display screen in millimetres. If Device is not set to deUser this parameter is ignored.

Example

vetSetDeviceParameters(CRS.deUser,viewingDistance_mm,width_mm, height_mm);

See also

vetSetStimulusDevice, vetSetViewingDistanceMM, vetLoadBitmapToMimicWindow

vetSetEIB_LEDsENABLED

This property sets the Eyetracker Interface Box LEDs on or off. Set this property to on (true) in order to turn the Eyetracker

Interface Box LEDs on, and set this property to off (false) in order to turn the LEDs off.

MATLAB Syntax

```
vetSetEIB_LEDsEnabled(LEDsEnabled);
```

See also

vetVideoSourceType, vetGetEIB_LEDsEnabled

vetSetEIB_XYOutputType

This property allows you to select the XY analog output type of the Eyetracker Interface Box (The values output to the two analog channels). These can either be 100 mm per volt, 1000 mm per volt, degrees elevation + azimuth (Helmholtz), or degrees longitude + latitude (Fick).

This value must be one of the following constants:

CRS.otMM100 - MM, 100 mm / V

CRS.otMM1000 - MM, 1000 mm / V

CRS.otHelm1 - 0.1 Volts per degree Helmholtz coordinates

CRS.otFicks1 - 0.1 Volts per degree Fick coordinates

MATLAB Syntax

```
vetSetEIB_XYOutputType(XYOutputType);
```

See also

vetGetLatestEyePosition, vetVideoSourceType, vetGetEIB_XYOutputType

vetSetFixationPeriod

Set the value of **fixationPeriod** to specify the amount of time, in milliseconds, a subject has to look in a particular location before the Toolbox considers it to be a fixation. When a subject is found to be fixating, the fixation flag in the results data sets will be set to

TRUE. The value specified will be rounded UP to the nearest multiple of the frame time (20ms for 50 Hz, 4ms for 250 Hz).

The minimum fixation period that can be specified is 100 ms, and the maximum fixation period that can be specified is 60000 ms.

When a subject is found to be fixating the fixation flag in the results data structure will be set to TRUE for the duration of the fixation. The MATLAB string specified using the **vetSetCallbackFixate** function will be executed, and the current fixation location can be returned using the **vetGetFixationLocation** function.

MATLAB Syntax

```
vetSetFixationPeriod(fixationPeriod);
```

Parameters

fixationPeriod – A positive (non-zero) integer scalar (1-by-1 matrix), in the interval [100,60000]. This value has units of milliseconds.

See also

vetSetFixationRange, vetSetCallbackFixate

vetSetFixationRange

Use the **vetSetFixationRange** function to specify the fixation tolerance range in millimetres. This value is used in the calculations that determine if a subject is fixating. A subject is deemed to be fixating if his gaze does not move by more than the Fixation Range in any one Fixation Period. The Fixation Period is set using the **vetSetFixationPeriod** function.

When a subject is found to be fixating the fixation flag in the results data structure will be set to TRUE for the duration of the fixation. The MATLAB string specified using the **vetSetCallbackFixate** function will be executed, and the current fixation location can be returned using the **vetGetFixationLocation** function.

MATLAB Syntax

```
vetSetFixationRange(fixationRange);
```

Parameters

fixationRange – A positive (non-zero) rational scalar (1-by-1 matrix). This value has units of millimetres.

See also

vetSetFixationPeriod, vetSetCallbackFixate

vetSetMimicBackgroundColor

This function specifies the background colour of the mimic window.

MATLAB Syntax

```
vetSetMimicBackgroundColor(mimicBackgroundColor);
```

Parameters

mimicBackgroundColor – A 3-by-1 or 1-by-3 RGB colour vector, each component of which is a rational scalar in the interval [0,1].

[1,0,0] produces 100% red.

[0,1,0] produces 100% green.

[0,0,1] produces 100% blue.

See also

vetCreateMimicWindow, vetSetMimicScreenDimensions, vetSetMimicFixationColor, vetSetMimicTraceColor

vetSetMimicFixationColor

This property sets the colour used to indicate fixations on the mimic window.

MATLAB Syntax

```
vetSetMimicFixationColor(mimicFixationColor);
```

Parameters

mimicFixationColor – A 3-by-1 or 1-by-3 RGB colour vector, each component of which is a rational scalar in the interval [0,1].

[1,0,0] produces 100% red.

[0,1,0] produces 100% green.

[0,0,1] produces 100% blue.

See also

vetCreateMimicWindow, vetSetMimicScreenDimensions, vetSetMimicBackgroundColor, vetSetMimicTraceColor

vetSetMimicPersistence

The **vetSetMimicPersistence** function specifies the duration of the trace that appears on the mimic screen. For example, setting **mimicPersistence** to 2 will cause the mimic screen control to display eye positions for the most recent 2 seconds only.

MATLAB Syntax

```
vetSetMimicPersistence(mimicPersistence);
```

Parameters

mimicPersistence – A positive rational scalar (1-by-1 matrix), greater than or equal to 0.05. This value has units of seconds.

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetSetMimicPersistenceType, vetLoadBitmapToMimicScreen, vetSetMimicTraceColor

vetSetMimicPersistenceStyle

The **vetMimicPersistenceStyle** function specifies the appearance of the mimic trace. Setting **vetMimicPersistenceType** to **CRS.psConstant** will cause the trace to appear as a constant color (good for picture search

tasks). If it is set to **psFade**, the trace will gradually fade into the background.

MATLAB Syntax

```
vetSetMimicPersistenceStyle(mimicPersistenceStyle);
```

Parameters

mimicPersistenceStyle – An integer value (1-by-1 matrix) which should be one of the following constants:

CRS.psConstant;

CRS.psFade;

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetSetMimicPersistence, vetLoadBitmapToMimicScreen, vetSetMimicTraceColor, vetSetMimicPersistenceType

vetSetMimicPersistenceType

vetSetMimicPersistenceType specifies the type of trace that is displayed in the mimic window control. To display a continuous trace illustrating eye position **vetSetMimicPersistenceType** should be set to **CRS.ptMotion**. To display eye position displayed as growing Fixation circles linked by motion traces **vetSetMimicPersistenceType** should be set to **CRS.ptMotionAndFixation**. Finally, to display just growing Fixations set **vetSetMimicPersistenceType** to **CRS.ptFixations**

MATLAB Syntax

```
vetSetMimicPersistenceType(mimicPersistenceType);
```

Parameters

mimicPersistenceType – An integer value (1-by-1 matrix) which should be one of the following constants:

CRS.ptMotion;

CRS.ptFixations;

CRS.ptMotionAndFixations;

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetSetMimicPersistence, vetLoadBitmapToMimicScreen, vetSetMimicTraceColor, vetSetMimicPersistenceType

vetSetMimicScreenDimensions

Use this function to set the dimensions of the mimic screen. Note that this function should be called before the mimic screen is created.

MATLAB Syntax

```
vetSetMimicScreenDimensions(Left, Top, Width,
Height);
```

Parameters

Left – Specifies the left edge of the mimic screen

Top – Specifies the top edge of the mimic screen

Width – Specifies the width of the mimic screen

Height – Specifies the height of the mimic screen

Example

vetSetMimicScreenDimensions(2, 10, 200, 150);

will set the dimensions of the mimic screen on its parent window so that it is located 2 pixels from the left, 10 pixels from the top, is 200 pixels wide and 150 pixels high.

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetMimicPersistence, vetMimicPersistenceType, vetLoadBitmapToMimicScreen, vetMimicTraceColor

vetSetMimicTraceColor

The **vetSetMimicTraceColor** function specifies the colour of the trace on the mimic screen.

MATLAB Syntax

```
vetSetMimicTraceColor(mimicTraceColor);
```

Parameters

mimicTraceColor – A 3-by-1 or 1-by-3 RGB colour vector, each component of which is a rational scalar in the interval [0,1].

[1,0,0] produces 100% red.

[0,1,0] produces 100% green.

[0,0,1] produces 100% blue.

See also

vetCreateMimicScreen, vetDestroyMimicScreen, vetSetMimicScreenDimensions, vetSetMimicPersistence, vetSetMimicPersistenceType, vetLoadBitmapToMimicScreen

vetSetStimulusDevice

The **vetSetStimulusDevice** function allows you to select the stimulus device which will be used by the Video Eyetracker Toolbox for calibration purposes. Valid devices are **CRS.deVSG**, i.e. a ViSaGe or VSG2/5; or **CRS.deVGA**, which is usually the Secondary Windows VGA Display.

Note: to set the Toolbox to work with a custom device, use vetSetDeviceParameters.

MATLAB Syntax

```
vetSetStimulusDevice(stimulusDevice);
```

Parameters

stimulusDevice – An integer value (1-by-1 matrix): One of the following constants:

CRS.deVGA;

CRS.deVSG;

See also

vetSelectVideoSource, vetStartTracking, vetSetDeviceParameters

vetSetUIMonitor

This function allows you to change the monitor that the Video Eyetracker Toolbox User Interface appears on. For example, if you are using a Windows Secondary VGA display configuration, you can use this function to make the VET User Interface appear on either the primary or secondary Windows monitor.

MATLAB Syntax

```
vetSetUIMonitor(UIMonitor);
```

Parameters

UIMonitor – An integer scalar value (0, 1, 2.. etc.). Valid values will depend on how many monitors you have in your system setup; but most Dual Windows VGA display systems should return 0 or 1.

vetSetViewingDistanceMM

This function allows you to set the Viewing Distance in Millimetres that the Video Eyetracker Toolbox uses. The Viewing Distance is the perpendicular distance between the centre of the stimulus display and the centre of rotation of the eye.

MATLAB Syntax

```
vetSetViewingDistanceMM(viewingDistanceMM);
```

Parameters

viewingDistanceMM – A positive, integer scalar (1-by-1 matrix).

See also

vetStartTracking, vetStopTracking

vetStartRecordingToFile

Call **vetStartRecordingToFile** to record the currently selected source to a file. The Toolbox does not perform any form of compression on the recorded stream and consequently requires a lot of space on a drive to record a file. 30 seconds of recorded data at 50 Hz requires approximately 200 Mb of storage.

MATLAB Syntax

```
vetStartRecordingtoFile(filename);
```

Parameters

Filename – A char array (Matlab string), containing a full filename and path. This specifies the name of the file which the streamed video signal will be saved to. You must specify the full path to your CAM file:

C:\myDirectory\myVideo.cam

See also

vetSelectVideoSource, vetStopRecording

vetStartTracking

This function initiates tracking and the collection of data. Note that any data that has already been collected will be lost when this call is made and data will only be collected if the subject has been successfully calibrated. (You can, however load a default calibration file instead if your subject is unable to fixate, or difficult to calibrate for other reasons).

MATLAB Syntax

```
vetStartTracking;
```

See also

vetStopTracking

vetStopRecording

Call **vetStopRecording** to stop the Toolbox recording the current video stream to file.

MATLAB Syntax

```
vetStopRecording;
```

See also

vetStartRecording, vetSelectVideoSource.

vetStopTracking

This function instructs the Video Eyetracker Toolbox to stop tracking. Eye position data will remain in the VET data buffer, and will be available for reading using the **vetGetBufferedEyePositions** function.

MATLAB Syntax

```
vetStopTracking;
```

See also

vetStartTracking

vetSetCallbackClearDisplay

This function is used during manual calibration of a user defined stimulus device. For example, LED or laser/galvanometer stimulus systems. The specified callback function will be executed when the VET calibration routine requests the stimulus display to be cleared.

MATLAB Syntax

```
vetSetCallbackClearDisplay(callbackString);
```

Parameters

callbackString – A character array (MATLAB string) containing the callback string to execute. This could, for example, be the name of an M-file function that handles the event.

See also

vetCalibrate, vetCalibrateAdvanced, vetSetDeviceParameters, vetSetCallbackDrawTarget, vetSetCallbackInitaliseDisplay

vetSetCallbackCollectResults

This function allows you to specify a MATLAB string to be processed whenever a new batch of results is ready to be collected. This MATLAB string normally defines the name of a MATLAB M file, which will execute when the callback occurs. This script should be designed to execute quickly, as any subsequent calls that collide may be dropped and lost.

MATLAB Syntax

```
vetSetCallbackCollectResults(callbackString);
```

Parameters

callbackString – A character array (MATLAB string) containing the callback string to execute. This could, for example, be the name of an M-file function that handles the event.

See also

vetIsEyeDataAvailable, vetGetBufferedEyePosition, vetGetLatestEyePosition

vetSetCallbackDrawTarget

This function is used during manual calibration of a user defined stimulus device, for example LED or laser/galvanometer stimulus systems. The specified callback function will be processed when the VET calibration routine requests that a target be drawn.

MATLAB Syntax

```
vetSetCallbackDrawYarget(callbackString);
```

Parameters

callbackString – A character array (MATLAB string) containing the callback string to execute. This could, for example, be the name of an M-file function that handles the event. This function will be called with two parameters; the X and Y locations of the target to be drawn (in mm) so for example, if callbackString is specified as 'myCallbackFunction', it will be called as: 'myCallbackFunction(xPosMM,yPosMM);'

See also

vetCalibrate, vetCalibrateAdvanced, vetSetDeviceParameters, vetSetCallbackClearDisplay, vetSetCallbackInitaliseDisplay

vetSetCallbackFixate

This function allows you to specify a MATLAB string to be processed whenever the subject makes a fixation. Typically, this string will contain the name of a MATLAB M-file function. This is called the callback function. Callback functions are typically designed to execute rapidly. If a second fixation occurs before the first callback has finished it's processing, that fixation will be ignored.

You can use the **vetSetFixationPeriod** and **vetSetFixationRange** functions to modify the criteria that the Video Eyetracker Toolbox software uses to determine if a fixation has taken place or not.

MATLAB Syntax

```
vetSetCallbackFixate(callbackString);
```

Parameters

callbackString – A character array (MATLAB string) containing the callback string to execute. This could, for example, be the name of an M-file function that handles the event.

See also

vetSetFixateRange, vetSetFixationPeriod

vetSetCallbackInitialiseDisplay

This function is used during manual calibration of a user defined stimulus device, for example LED or laser/galvanometer stimulus systems.

The specified callback function will be processed when the VET calibration routine requests that the stimulus device is initialised.

MATLAB Syntax

```
vetSetCallbackInitialiseDisplay(callbackString);
```

Parameters

callbackString – A character array (MATLAB string) containing the callback string to execute. This could, for example, be the name of an M-file function that handles the event.

See also

vetSetCallbackClearDisplay, vetSetCallbackDrawTarget

vetSetCallbackRegionChanged

This function allows you to specify a MATLAB string to be processed whenever the direction of gaze first enters a new Region-Of-Interest.

MATLAB Syntax

```
vetSetCallbackRegionChanged(callbackString);
```

Parameters

callbackString – A MATLAB string containing the callback string to execute. This could, for example, be the name of an M-file function that handles the callback.

See also

vetAddRegion, vetDeleteRegion, vetClearAllRegions, vetRegionCount

Appendix B Imaging Geometry

Illumination Geometry

The Video Eyetracker Toolbox illuminates the eye using two sets of infrared diodes identically positioned on opposite sides of the infrared camera. Each set of diodes will create a glint, known as a Purkinje image, as shown in the diagram below:

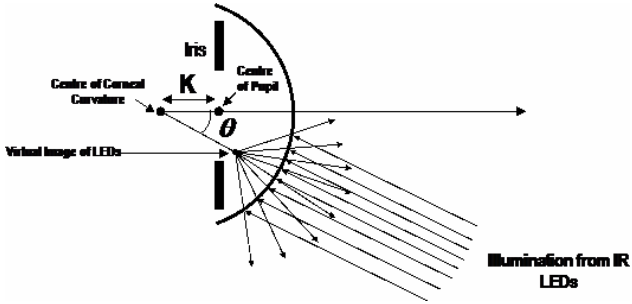


Fig 65. Illumination Geometry

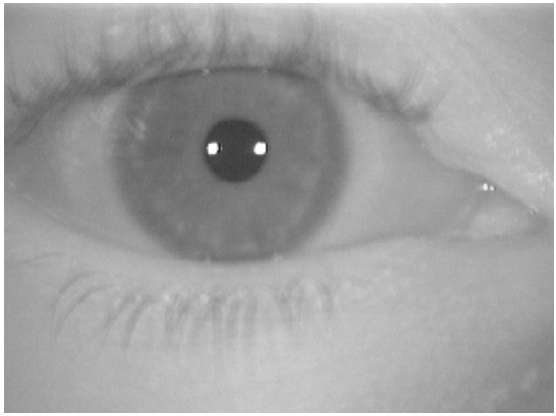


Fig 66. Typical Video Image

Imaging the eye using two infrared illumination sources creates a dark pupil with two bright, horizontally separated Purkinje glints, as shown in Fig 66:

The Purkinje glints will remain bright, compact and constantly separated provided they are both imaged off the corneal surface. This gives allowable eye rotations of up to 40 degrees and creates even ilumination over the whole eye.

The Toolbox's dedicated image processing algorithms are designed to locate the pupil and both Purkinje glints in real time. The algorithms exploit their size, shape, intensity and relative locations to optimise tracking efficiency and, once located, their centres are determined to sub pixel precision by ellipse fitting. Tracking is indicated by superimposing the fitted ellipses onto the live eye video window as shown below:

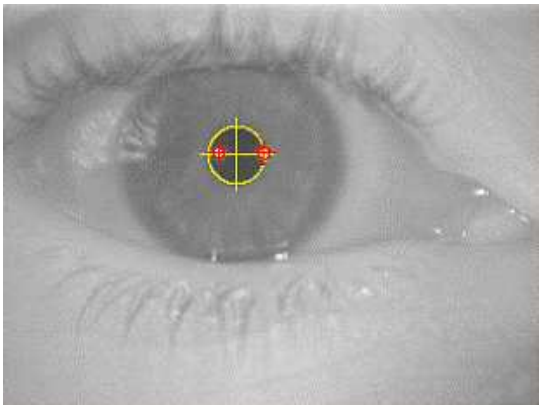


Fig 67. Tracked Video Image

Calibration Geometry

Calibration is required first to convert the image feature positions into a computed view direction. This direction, together with the computed eye position, then requires further calibration to compute the corresponding gaze screen position. Both halves of this calibration process are achieved by requesting the subject to view a number of screen targets from a known viewing distance.

Placing the ilumination sources symmetrically on either side of the camera implies that the centre of corneal curvature in each image is simply the midpoint between the resulting purkinje images.

This, combined with requesting the subject to view a number of screen targets from a known distance (which requires the user to rotate the eye through known angles) enables the Toolbox to determine the 3D distance between the cornea and pupil centres. This distance is denoted as **K** in the above illumination diagram.

Once **K** is known for a particular individual and camera setting, the system can now determine the direction of gaze relative to the camera. This gaze direction is denoted in the equation below as the vector [Cx, Cy, Cz] and the centre of corneal curvature as the vector [Xo, Yo].

$$\begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix} \begin{bmatrix} C_x \\ C_y \\ C_z \end{bmatrix} + \begin{bmatrix} \alpha & \beta \\ \gamma & \delta \end{bmatrix} \begin{bmatrix} X_0 \\ Y_0 \end{bmatrix} + \begin{bmatrix} X_{offset} \\ Y_{offset} \end{bmatrix}$$

Fig 68. Calibration Equation

The remaining unknowns in the calibration equation are the coefficients a to h, alpha to delta and [Xoffset, Yoffset]. These are given initial estimates which are then refined by requesting the subject to view a set of screen targets with known positions.

Fig 69. Calibration Targets

The Toolbox computes the differences between where these targets are and where the Toolbox calculates them to be using the initial estimates. These differences are used to create an error term which is then minimised by altering the calibration parameters using iterative numerical techniques. Those values which minimise this error term are then used in the above calibration equation for all subsequent analysis.

The Toolbox can now determine the position and orientation of the eye relative to the monitor and has all the information necessary to determine the view axes for all subsequent images. It is therefore able to determine the current point of fixation on the monitor from the relative positions of the pupil and Purkinje centres in subsequent images.

Appendix C Template for Fixed Mount EyeLock Headrest

The fixed mount EyeLock headrest is designed to be bolted directly to a CRS Experimental Workbench or table top for extra rigidity. This requires drilling two 20 mm diameter holes into the top of the workbench to a depth of at least 20mm followed by two concentric 8.1mm holes through the remainder of the worksurface. A cross section through one of these holes is shown below.

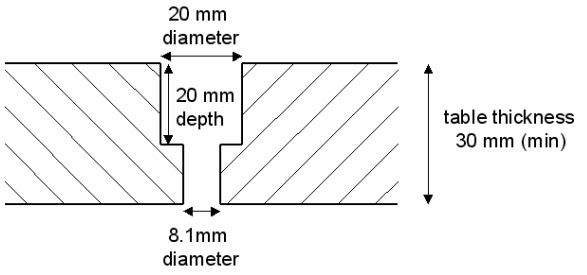


Fig 70. EyeLock Hole Cross-Section

To prevent unnecessary stressing of the headrest, it is important that these holes are positioned accurately relative to each other and to the edge of the workbench. Use the template below to ensure all holes are drilled correctly. Take care not to damage this template so that it remains available for future use.

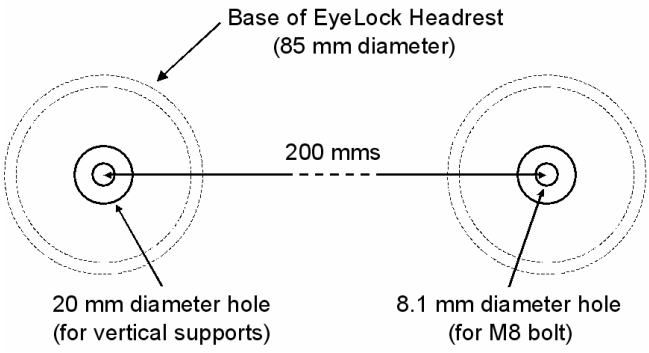


Fig 71. Positioning of EyeLock Holes

Appendix D Technical Specification

The following specifications state what the Toolbox is designed to achieve in normal use provided reasonable care has been taken during imaging set-up and calibration. The stated variation in tracking accuracy is dependent on each subject's ability to fixate on the calibration targets.

Technical Specifications

Measurement Technique	Video utilising Pupil and dual first Purkinje images.
Imaging Technique	Infrared camera plus 2 infrared sources
Sampling Frequency (50 Hz/High-Speed)	50 Hertz / Up to 250 Hertz
Latency	20 msec / 4 -- 100 msec*
Resolution	0.05 Degree
Pupilometry Range	3 – 10 Millimetres
Pupilometry Accuracy	+ / - 0.5 Millimetres
Tracking Accuracy	0.125 – 0.25 Degree
Horizontal Range	+ / - 40 Degrees
Vertical Range	+ / - 20 Degrees
Allowable Head Movement	+ / - 12 Millimetres (50 Hz) + / - 8 Millimetres (250 Hz)
Measurement Units	Fick and Helmholtz co-ordinates in degrees or screen position in millimetres.

* The maximum 100 msec latency figure quoted for the High-Speed System is due to the time required for the Eyetracker Interface Box to create an analogue output for the tracked eye positions.

Appendix E Hot Mirror Spectral Transmission

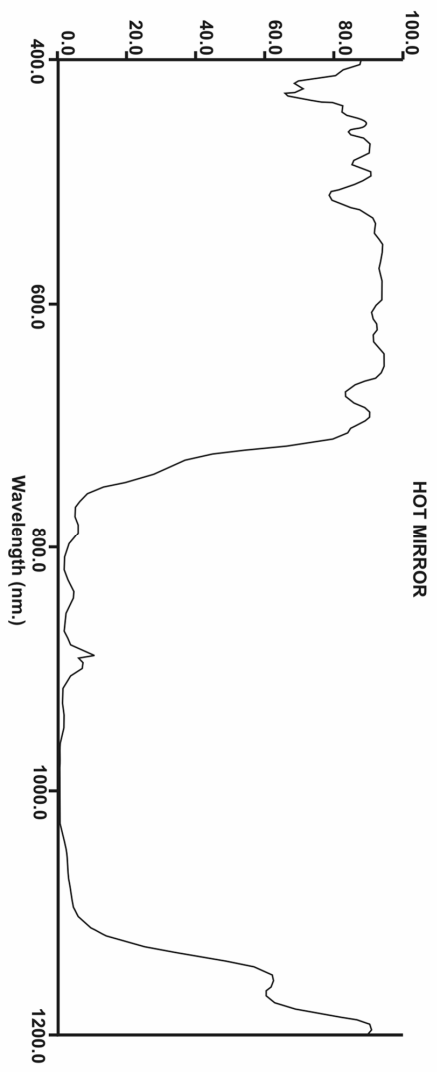


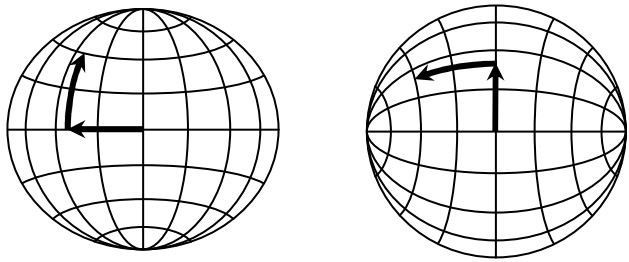
Fig 72. Spectral Transmission of Infrared Mirror

Appendix F Fick and Helmholtz Coordinates

Technical Description

The Video Eyetracker Toolbox is able to return the view position either in horizontal / vertical millimetres or in Fick or Helmholtz angle co-ordinates.

The Fick system of angular coordinates specifies the horizontal (longitude) component first followed by the vertical (latitude) component. The Helmholtz system specifies the vertical (elevation) component first followed by the horizontal (azimuth) component. These coordinate systems are demonstrated in the figure below.



Fick Coordinates *Helmholtz Coordinates*

Fig 73. Angular Coordinate Systems

It is important to be aware of which angular coordinate system is being used, as their angular components do not commute! For example, a longitude of 50 degrees followed by a latitude of 30 degrees is not equivalent to an elevation of 30 degrees followed by an azimuth of 50 degrees.

Appendix G
Data Returned by the Toolbox

Technical Specification

The table below contains a list of all of the entries stored in the MATLAB **Data** structure which is returned by the functions: **vetGetLatestEyePosition** and **vetGetBufferedEyePositions**.

Data.timeStamps	The time in milliseconds since tracking started
Data.tracked	If the frame is successfully tracked this value is set to 1 = TRUE, otherwise it is 0 = FALSE
Data.calibrated	If the subject has been calibrated this value is set to 1 = TRUE, otherwise it is 0 = FALSE
Data.fixation	If the subject is fixating this value is set to 1 = TRUE, otherwise it is 0 = FALSE
Data.dropped	If the frame has been dropped (not processed) by the Toolbox in order to keep real-time it is set to 1 = TRUE, otherwise it is 0 = FALSE
Data.pupilDiameter	The diameter of the test subject's pupil in millimetres
Data.mmPositions	Direction of gaze projected onto stimulus display in mm: [X, Y]
Data.ficksPositions	Eye rotation in Fick coordinates [Longitude, Latitude]
Data.helmholtzPositions	Eye rotation in Helmholtz coordinates [Elevation, Azimuth]
Data.region	Current region number.
Data.digitalIO	A value containing the combined digital IO values (see page 53 for details).
Data.trigIn	**High-Speed system only.** A +/-5 volts TTL or analogue voltage input signal which is returned in the range of +/- 1

Appendix H
Troubleshooting

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Poor performance or complete eye tracking failure is likely to be the result of poor operating conditions rather than a fault with the Toolbox itself. The troubleshooting guide is designed to eliminate those problems which are most often experienced by new users. If, after making full use of this guide, you are still experiencing problems, please create a Ticket using the Cambridge Research Systems support postal (www.crsltd.com/support/login)

The following sections use example video images from the 50 Hz system although the issues apply equally to the 50 Hz and 250 Hz versions. Before proceeding further, it may be useful to make a brief comparison between the video images obtained from the two systems.

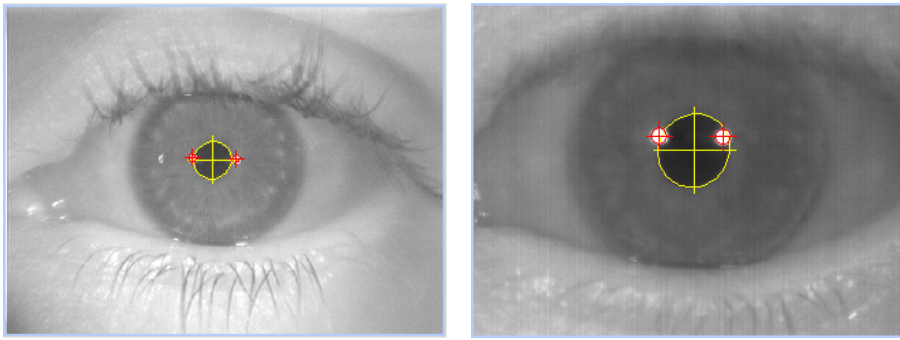

Fig 74. 50 Hz (Left) and 250 Hz (Right) Video Images

These images of the same test subject were taken using the 50 Hz CCD and 250 Hz CMOS cameras. The noticeable differences are clarity, scale and the size of the Purkinje glints. The lower clarity in the 250 Hz system is partly due to using a high-speed CMOS sensor and partly due to reduced depth of focus from using a wider aperture lens to gather sufficient light. However, the effects of lower image clarity are compensated for by using higher optical magnification and larger Purkinje glints. In tests, both systems meet the same specifications for accuracy although the High-Speed version will tolerate slightly less head movement.

System slow to calibrate

The calibration process requires the subject to fixate on a series of screen targets. The system will not advance to the next screen target until it has made a number of consistent measurements from the current fixation. A delay in advancing to the next screen target may be caused by head movement which is tolerated during normal use but not during calibration. Alternatively, slow calibration may be the result of intermittent or noisy eye tracking – see relevant sections below.

System fails to calibrate

Refusal to advance beyond the first screen target during calibration will either be the result of the system failing to locate the Purkinje glints or the pupil, or both. The actual mode of failure will be shown in the live image window by the absence of one or more fitted ellipses – see relevant section(s) below.

System fails to track the eye

A sudden failure to track the eye will either be the result of the system failing to locate the Purkinje glints or the pupil, or both. The actual mode of failure will be shown in the live image window by the absence of one or more fitted ellipses – see relevant section(s) below.

System fails to track the Pupil

Failure of the system to locate the pupil could be due to one or more of the following:

- The pupil is no longer fully contained within the image or very close to the image edge.

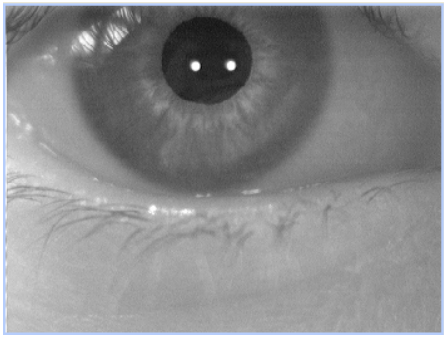

Fig 75. Poorly Positioned Eye

- The eye is no longer in focus due to head movement away from the infrared mirror. Ensure that the subject maintains contact with the headrest at all times and refocus if necessary.

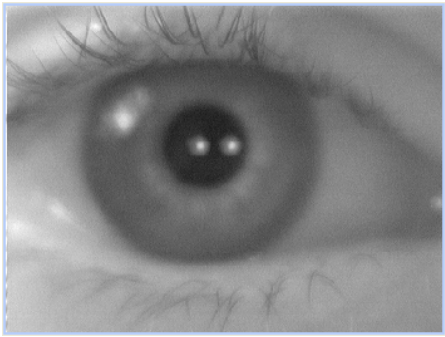

Fig 76. Out of Focus Eye

- The eyelid is partially obscuring the eye.

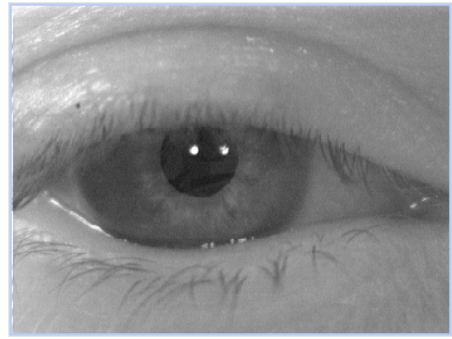

Fig 77. Pupil Obscured by Eyelid

- The eye is looking beyond its intended range of rotation. If this occurs during calibration, it may be necessary to reduce the screen scale factor in the calibration advanced settings window. (Refer back to the subject calibration section for further details.)

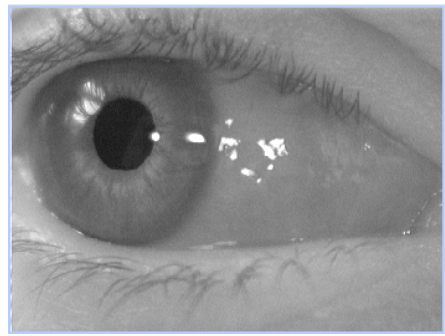

Fig 78. Excessive View Angle

- The image contains a shadow or foreign object that creates a region darker than the pupil itself.

System fails to track the Purkinje Glints

Failure of the system to locate both Purkinje glints could be due to one or more of the following:

- The pupil is no longer fully contained within the image.
- The image contains a spurious bright glint which is lies close to the pupil. This may be caused by certain types of spectacles or from secondary sources of infrared illumination.

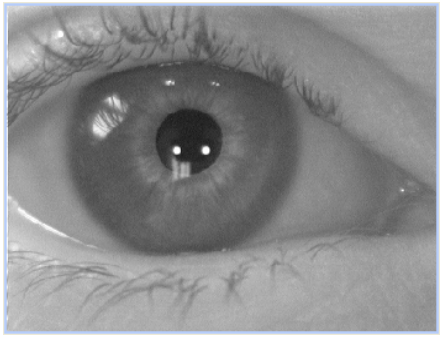

Fig 79. Spurious Additional Glints

- The eye is no longer in focus due to head movement away from the infrared mirror (see Fig 76).
- One of the Purkinje glints has merged with a spurious glint and is being rejected on position / size / shape criteria. This is often the result of the eye rotating to the point where one of the Purkinje glints no longer lies on the corneal surface (see Fig 78).

Eye tracking appears inaccurate

Occasionally, there may be consistent errors between where the subject is looking and where the system thinks the subject is looking. This may be solved by checking the following:

- The eye may be slightly out of focus due to head movement away from the infrared mirror. Ensure that the subject maintains contact with the headrest at all times and refocus if necessary.
- The eyelid may be obscuring the pupil slightly, which would reduce the accuracy of finding the pupil centre.
- The system may have been poorly calibrated or lost calibration due to movement of one of the headrest components. Ensure that all headrest adjustments are correctly and securely set and then recalibrate.

Eye tracking appears noisy, erratic or intermittent

In normal use, the Toolbox will track the subject's point of fixation with angular noise of between one quarter and one half of a degree (which is approximately 2.5 – 5mm positional error at a viewing distance of 500mm). These specifications can be achieved by ensuring that:

- The radial lines on the iris are clearly visible (i.e. the pupil / iris is in focus -- not the eyelashes)
- There are no bright spurious glints close to the pupil
- The pupil is in the centre of the image and not occluded by the eyelid in any way

These are illustrated in Fig 80:

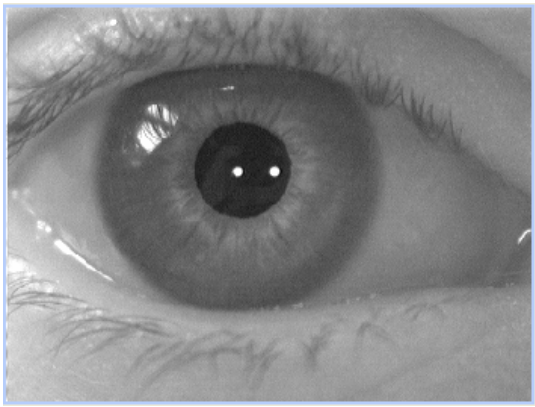

Fig 80. Good Video Imaging Conditions

High-Speed Eyetracker Only

Intermittent tracking can also be caused by the PC failing to keep up with the video frame rate. If this occurs, the user should check that the PC is not performing any non-vital background processes. If the problem continues, the user should either reduce camera speed in the **Select Video Source** window or if this is not viable, it may be necessary to consider a PC upgrade.

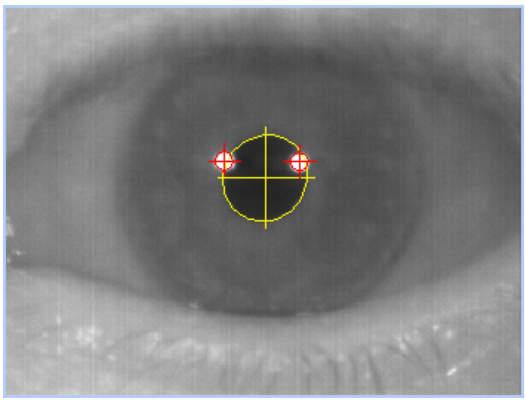

Fig 81. 250 Hz Eyetracking

Noisy eye tracking measurements may be due to one of the following causes:

- The eye is no longer in focus due to head movement away from the infrared mirror. Ensure that the subject maintains contact with the headrest at all times and refocus if necessary.

- Poor pupil contrast caused by room or outdoor illumination interfering with the system's infrared eye illumination. This may be reduced by altering the room lighting, shielding the headrest from sources of outdoor illumination, or removing spectacles if necessary.

- Poor pupil illumination. Ensure both sets of infrared LEDs are not occluded in any way and that both Purkinje glints appear compact and visible in the video image.

High-Speed System Only

- The High-Speed Video Eyetracker Toolbox has an adjustable iris which should **always** be set fully open so that the image is as bright as possible (see Fig 82). Accidental adjustment of the lens iris will result in a darker image as shown in Fig 83 which will result in noisy or intermittent tracking.

Fig 82. Focus and Iris Rings on High-Speed Camera Assembly

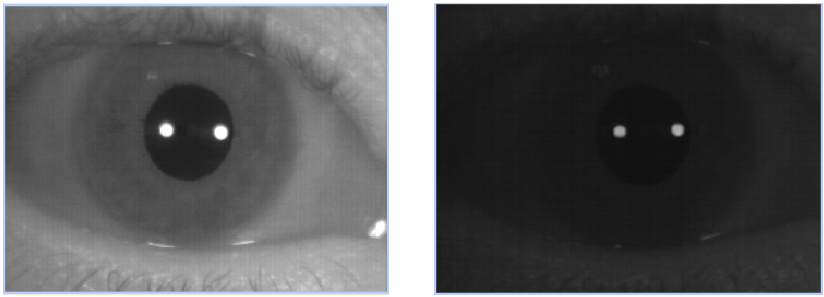

Fig 83. Iris fully Open (Left) and partially Closed (Right)

Notes